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Rational choice in field archaeology

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Abstract

In the present article I attempt to apply advances in the study of instrumental and epistemic rationality to field archaeology in order to gain insights into the ways archaeologists reason. The cognitive processes, particularly processes of decision making, that enable archaeologists to conduct the excavation in the trench have not been adequately studied so far. I take my cues from two different bodies of theory. I first inquire into the potential that rational choice theory (RCT) may have in modeling archaeological behaviour, and I define subjective expected utility, which archaeologists attempt to maximize, in terms of knowledge acquisition and social gain. Following Elster's criticism of RCT, I conclude that RCT's standards for rational action do not correspond with those ostensibly used in field archaeology, but that instrumental rationality has a prominent role in the "archaeological experiment". I further explore if models proposed as reaction to RCT may account for archaeological decision making. I focus on fast and frugal heuristics, and search for archaeological illustrations for some of the cognitive biases that are better documented in psychological literature. I document confirmation and congruence biases, the endowment effect, observer-expectancy bias, illusory correlation, clustering illusion, sunk cost bias, and anchoring, among others and I propose that some of these biases are used as cognitive tools by archaeologists at work and retain epistemic value. However, I find formal logic to be secondary in the development of archaeological reasoning, with default logic and defeasible logic being used instead. I emphasize scientific knowledge as an actively negotiated social product of human inquiry, and conclude that to describe rationality in field archaeology a bounded rationality model is the most promising avenue of investigation.

Keywords

Excavation, rational choice theory, rationality, biases, archaeological reasoning, logic of scientific discovery

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Introduction

In the present article I attempt to use advances in the study of epistemic and instrumental rationality to field archaeology in order to gain insights in the way in which archaeologists reason. While hypothesis testing and explanatory theories are often discussed in processual and post-processual archaeological literature, it is generally with regard to grand scale archaeological interpretation (Watson 1971, Gibbon 1989, Clarke 1968, Thomas 2005), occasionally about *rational choice* or *satisficing* models in archaeology (Kohler 1986, Binford 1967, 1978), but only rarely dealing with belief formation or decision making during the archaeological excavation (Hodder 1999, Lucas 2001, Yarrow 2008; Read 1978). Theories of scientific reasoning have not been adequately applied to archaeology, with rationality studies or bias literature having been rather ignored by archaeologists. Moreover, archaeology's versatile relation with anthropology and its comparative status as a newcomer with an ambiguous position among social sciences has made it less available to the insights of historians and philosophers of social sciences (Dunnell 1982, Read and LeBlanc 1978, Wylie 1989, Preucel 2006).

In what follows, I begin by suggesting how archaeology can benefit from rationality studies (I). I then move on to investigate potential applications of unbounded rationality and bounded rationality models in archaeology. For this purpose, I consider instrumental rationality theories in response to Elster's (2007) criticism of rational choice theory (II). As a counterpart I analyze epistemic rationality at work during the processes of scientific reasoning by considering archaeologists' decision making processes with respect to bias studies and Gigerenzer's fast and frugal heuristics (III). I finish by offering a few tentative conclusions as to how archaeologists reason (IV).

I. The context

Archaeologists study our past through the investigation of archaeological sites, complex aggregates of material remains of past societies, and must destroy those remains in order to observe and interpret them. Excavation – the traditional and irreplaceable method of practicing archaeology – cannot be done without removal of soil, which in turn cannot be done without irreversibly destroying the macro- and micro-organization of all soil strata. This is key to the stratigraphic, and thereby historical, sequence of ancient man's life at any given site (Roskams 2001, Renfrew and Bahn 2008, Lucas 2001). As opposed to scientists such as histologists dissecting a tissue sample, or geologists breaking a rock to reveal a fossil, archaeologists destroy an object (the site) whose cultural parameters make it non-repeatable and non-renewable. Different sandstone blocks or samples of muscle tissue will also have different discrete physical structures; nevertheless they will not exhibit any cultural variability. Decisions as to which layer to excavate next and how to excavate it are crucial and entail an earnest responsibility for the archaeologist. Indeed, while the benefits of digging here instead of there are unpredictable (will they bring irrelevant information, help to corroborate a current explanation, or refute a certain theory), the costs of a wrong decision, and of the potential loss of information, are high. One would certainly want to make sure the excavation is rationally conducted.

Rationality is a normative notion, an optimizing strategy for behaviour and thought. Two types of rationality are thus recognized: instrumental and epistemic (e.g. Stanovich et al 2011). Instrumental rationality is concerned with optimization of the individual goal's fulfillment, that is, the choice between options based on which option has the highest expected utility (Hastie and Dawes 2001, Baron 2004). Epistemic rationality is concerned with how well beliefs map onto the actual structure of the world (Audi 2001, Manktelow 2004). The former is practical, and concerns behaving in the world so that one obtains what one most wants, given the available physical and mental resources. The latter is theoretical and deals with the conclusions one is justified in drawing from available evidence and the resulting beliefs one would be justified to have. Elsewhere they are described as rationality 1 (rationality of purpose, cf. instrumental), reasoning in a way which helps one to achieve one's goals, therefore defined by a personal criterion; and rationality 2 (rationality of process, cf. epistemic), reasoning in a way which conforms to an impersonal criterion, a supposedly appropriate normative system such as formal logic (Evans and Over 1996, Chater and Oaksford 2004).[2]

In field archaeology rationality can be studied on both these two levels, investigating both the optimality of decisions made by trench supervisors as well as the soundness of their formal reasoning.

II. Instrumental rationality in field archaeology

One of the most popular theories accounting for the actions of people on goal achieving trajectories is rational choice theory (RCT) (Elster 1986), which sees social actors' rational behaviour as maximizing the expected utility of their actions (Evans and Over 1996, Sen 1977).[3] To model social and particularly economic behaviour, RCT has assumed that one's own interests, although a subset of human motivations, are invariably preeminent and basically dictate one's behaviour. Amartya Sen has emphasized that such a reductionist definition of rationality would make people who pursue it mere rational fools, who make rational decisions strictly to maximize personal gain with no regard for moral considerations. But what does choosing the best option and maximizing expected utility mean for scientists engaged in research? In their case, the expected utility must have to

[2] The recent distinction introduced by Stanovich et al. (2011) between fluid and crystallized rationality, which builds on general intelligence theory, will not be used here, although in a large sense fluid rationality can be correlated with rational action and instrumental rationality, while crystallized rationality procedures offer the possibility for both rational responding (crystallized facilitators) and irrational behaviour (crystallized inhibitors) (id., 194). Other classifications have been proposed (five types of rationality in Plantinga, 1993), but they need not detain us here.

[3] General accounts of RCT, Hastie and Dawes 2001, Coleman and Fararo 1992, Gilboa 2010; cf. Sen 1995, Maldonato 2010.

do with knowledge gain. I use the term knowledge here as it is pragmatically defined in Davenport and Prusak (1998, cf. Ackoff 1989), namely "a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport and Prusak 1998: p.5; for them, data is a set of discrete, objective facts about events, and if it can be made to carry a message to us, it becomes information). More specifically then, what is a positive outcome, or utility, or the desirable result that can be at the end of the field archaeologist's decision in the trench, as opposed to a negative outcome? For research excavations (on sites that are not threatened), the positive outcome is maximizing archaeological knowledge acquisition and social gain while minimizing damage to the site as a whole. For rescue excavations (under time pressure, ahead of development), the positive outcome is maximizing archaeological knowledge acquisition, social gain and artefact retrieval. Two observations are required here. First, social gain is an umbrella term referring here to restituting to visitors and a larger (layman) audience a sense of the past human experience, by means of public presentation through museums and accessible sites, but also to perpetuating archaeological praxis and the associated professional identity. The second observation is that, as long as a site is not threatened, the priority is not to retrieve as many artefacts as possible from the total of artefacts buried there, although from whichever unit of the site that ends up being excavated, total retrieval is recommended. Ideally, one would generate understanding and meaning on grounds of little but meticulous excavation. From a site that has been sacrificed by society to development, it is perhaps acceptable to salvage material culture which is our common heritage even when not all of it can be recorded or understood properly. Ideally though rescue archaeology would be able to appropriate the methods of research archaeology, although this can only be at the expense of the number and size of sites that are investigated before being destroyed by development.

Elster's criticism of RCT

I will try to investigate here the extent to which one can use RCT as an instrument to fathom what happens in archaeology, where the motivations are not financial but gnoseological. I conclude that RCT is of limited use in modeling how archaeologists make decisions in the field.

RCT has been recently the subject of much criticism, reviewed by Zey (1992: pp. 9-28) and Zsolnai (2009: pp. 57-76). I follow here however Jon Elster's poignant analysis (Elster 2007: pp. 191-213). In the rational choice paradigm, for an action to be rational, it needs to satisfy three requirements and in reality these three requirements can hardly ever be fulfilled. The theory seems to fail on grounds of irrationality of actors with respect to RCT's definition of rationality. [4]

[4] Elster 1997: p.209 has even suggested that we drop the idea of rationality altogether and use non-irrationality instead.

First of all, such an action must be optimal, in other words, it must be the best means of satisfying an agent's desires given her beliefs about the existing options and their consequences. For a rational/optimal solution to be at all possible, one's preferences have to be transitive, and one's preferences must be complete. For the preferences to be transitive, it is required that, should the agent be able to make three possible decisions, and assuming that they should prefer A to B and B to C, then they should also prefer A to C. If they in fact prefer C to A, the set of preferences is intransitive and in such an instance the decision maker is susceptible to "improving themselves to death", exchanging object A for C, then C for B, then B for A, and ending up in the original situation after resource-consuming behaviour. For the preferences to be complete, on the other hand, the agent should always be able to say whether between two expected outcomes one of them is preferred or if they are of equal worth; a state of non-determination preempts the possibility of rational decision making.

In archaeology preferences are not always transitive and complete. Some choices can be superior as well as inferior to each other in different respects. Given the destructive nature of archaeological excavation, one's options also depend on one's risk aversion. In archaeology, risks are mainly related to loss of information (which may have been converted into knowledge). For example, if one thinks one sees a slight discoloration of a somewhat oval shape in a floor, one will often consider it to be a pit and start excavating it before other features, in order to prevent potentially later material from contaminating the material retrieved from the floor. However, under particular time pressure (due to conservation needs, for example), one might decide to just record the discoloration, remove a thin arbitrary layer over the whole surface, to which a different context number is given, make a note of the possible contamination, then check if the putative pit is more easily recognizable. In fact, it would be safest to split any identified stratigraphic unit[5] in say, five different units. The material from these may be later re-combined to prevent any possibility of deposits having been accidentally overdug, but the side effect is that this would considerably slow down the stratigraphic recording, find processing, and interpretation.

Completeness of preferences cannot be achieved either, despite the fact that outcomes tending to support preexisting beliefs may be preferable (see below, confirmation bias). But in general there is always the chance, given the high unpredictability of the outcome, that different outcomes address different explanatory models in different degrees, partly confirming a first model, partly disconfirming a second, and bringing new evidence that can only be explained by a third.

Finally, often our options may exhibit decreasing marginal utility or increasing marginal utility. An example of the former would be the fact that the first very few clues about the

[5] A stratigraphic unit (or context) is defined as any archaeological deposit resulting from human or geological activity that has distinguishable physical characteristics and which can be interpreted as functionally or chronologically relevant to the history of the site. The definition is extended to include masonry as well as the interfaces created by removal of such units (Pavel 2010).

nature of an unknown archaeological feature contribute the most to shape our understanding of a trench, with subsequent clues only reinforcing the interpretation and towards the end being downright redundant. An example of the latter would be the fact that having identified and excavated n as opposed to n-1 randomly chosen burials from a necropolis is better than having excavated n-1 as opposed to n-2, since the larger the sample, the smaller the margin of error and the bigger the knowledge benefits from statistical analysis.

Following Elster's analysis, the rationality of a decision is also grounded in the fact that the decision-maker's beliefs must be as well supported by evidence as possible. Nevertheless, the agent constantly updates her beliefs, potentially revising beliefs pertaining to decision A because of new evidence/observations, while decision B is still being assessed, and so on. This process of belief revision is powered by Bayesian inferences, using initial subjective ("prior") probabilities to determine the probability that a hypothesis is true given such observed evidence. More importantly though, often the very existence of archaeological evidence is a result of pre-existing beliefs (Hodder 1999). For example, when one first discovers a courtyard surface decorated with multi-coloured pebbles, then moves into an area where the pavement is very poorly preserved, one is still able to identify it as such. Otherwise its rests would perhaps not have been identified or recorded, and therefore they would not have become evidence at all.

Finally, for a decision to be rational in the RCT paradigm, the array of evidence that supports the beliefs must result from an optimal investment of effort in information gathering. Any decision is accompanied by the shadow action (Elster 2007) of gathering information necessary for assessing it. But how much information archaeologists gather depends on how much information they (and the social group/scientific school of thought of which they are part) need. Their desires, biases, experience and education structure how and where the evidence is looked for.

One of the important reactions to the perceived flaws of RCT was the design by Herbert Simon of bounded rationality theory (Simon 1990), where rationality is no longer an optimization strategy. The cognitive limitations of the decision maker render such a strategy an unachievable ideal. Our search for decision cues in real life cannot be exhaustive; instead, it ought to be a set of heuristics, algorithms that are not very logical but efficient in decision making in an uncertain world, and pivotal in achieving practical goals under conditions of limited (physical and mental) resources. Simon famously defined human rational behaviour as being "shaped by a scissors whose blades are the structure of task environments and the computational capacities of the actor." (id: p.7). He argued that people are not optimizing, but *satisficing* (Simon 1956), that is, choosing the first option which meets minimal requirements. Gerd Gigerenzer further elaborated on the implications of bounded rationality, developing the theory of fast and frugal heuristics (Gigerenzer and Goldstein 1996, Gigerenzer, Todd, and the ABC Research Group 1999, Gigerenzer and Selten 2002). If our rationality is bounded, then our heuristics must be frugal in what they take into account, fast in their operation, and fit to reality (Forster 1999). Field archaeologists are indeed quite prone to use fast and frugal heuristics, often under the guise of biases.

III. Epistemic rationality in field archaeology

After Kuhn has challenged the positivistic paradigm in epistemology, it became evident that formal logic does not account for how we build arguments (Toulmin 1979, Harman 1999). Also, formal mechanisms such as deduction do not account for how we make decisions or for how we reach conclusions (Oaksford and Chater 2002; Tweney and Chitwood 1995), and clearly scientific reasoning is more than just algorithms (Nersessian 1992). For archaeological reasoning formal logic gives in to defeasible logic, and archaeological argumentation is conceived as having to do less with falsification or verification and more with strengthening or weakening hypotheses. (e.g. Doerr et al. 2011).

On a very general level, reasoning is seen as the mental process that attempts to tie thoughts and actions in an unbroken series of links (Smith 1990). One solid modern tradition rooted in Dewey's work sees reasoning (called reflective thought, critical thinking and so on) as basically dealing in the formulation of sound arguments. Dewey himself was describing it as "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends" (1910: p.9).

Toulmin et al (1979: p.13) have theorized reasoning as marshaling reasons in support of a claim so as to show how those reasons succeed in giving strength to the claim. They discuss reasoning in terms of claims, grounds, warrant, backing, modal qualifiers, and possible rebuttals (id: pp. 25sq.)

This "argumentative" tradition of reasoning is not the only one, and to be sure many have contested that these processes could be spelled out in the mind as they are presented by Toulmin (Gigerenzer 1999). For Gilbert Harman, reasoning is not the conscious rehearsal of argument; it is "a process in which antecedent beliefs and intentions are minimally modified, by addition and subtraction, in the interests of explanatory coherence and the satisfaction of intrinsic desires […] one may not even be conscious that any reasoning at all has occurred (1999: p.56).

Using only valid logic operations does not get one too far in putting order in a day's worth of information. How does one deal with conflicting data? As a matter of fact, archaeological data is rarely directly contradictory, such as when we collect both information A and information non-A. One such instance would be when, following one line of reasoning, supported by some of the evidence, wall 1 is judged to be earlier than wall 2, but, following a different line of reasoning (based on different or the same evidence), wall 1 is judged later than wall 2. This is an absolute contradiction, but the evidence supporting it is hardly ever completely certain, and is often the result of interpretation. In fact, given a number of equally ambiguous clues, the ones supporting the more cogent conclusion may be perceived as less ambiguous. The credibility of the whole reinforces the credibility of the parts. Should one reach an interpretative cul-de-sac, or an unacceptable conclusion, one reassesses the evidence in a classical backtracking problem, by going back to the most recent piece of evidence (the closest clue) and choosing another interpretation for it, one that originally had been deemed less probable, and then checks if this permits an acceptable overall conclusion. If not, one goes back to an even earlier knot, takes up again the other branch, and continues until coherence has been achieved.

However, most of the time, there are no such absolute contradictions, but rather interpretations conflicting in different degrees, but still in the same paradigm, such as when some evidence suggests this was a storage pit, and some suggests this was a refuse pit, when in fact it may have been a storage pit filled with refuse when it was no longer in use for storage, or even a pithos pit. The most successful use of formal deductive logic is indeed for producing the Harris Matrix of the trench/of the site – a graph of all stratigraphic units at the site (be they called contexts, or layers) in chronological order. By applying reasoning of the type [wall 1 earlier than floor 2, and floor 2 earlier than floor 3, therefore wall 1 earlier than floor 3] all units can be arranged in the matrix.

The level at which data may appear to be anomalous can also be very subtle, and depends entirely on the researcher's problem setting abilities. Indeed, there is no such thing as data anomalies in the absence of research expectations. It should also be recalled that there are many instances when archaeological evidence is not conclusive, even for simple examples. It is sometimes impossible to ascertain whether four connected walls belong to the same building, let alone what the function of the building may have been. This fundamentally stems from the non-repeatable nature of the archaeological experiment and the fact that, except in the most carefully designed projects focusing on well circumscribed issues, excavators work with unrepresentative samples.

Biases

An increasing number of experiments with sound methodologies over the past decades have led to a better understanding and quantification of biases. Some biases are acquired through education and experience, but some are probably innate and based on instincts and sensorial particularities (Caverni et al 1990). They can be defined as recurring cognitive errors with epistemic value, cognitive adaptations for decision making (Saarikoski 2007, Tweney and Chitwood 1995). In the paradigm of fast and frugal heuristics, they are perceived as having the potential, under certain circumstances, to make one a more effective decision maker. While most of the biases discussed below are considered by Stanovich et al. (2011) to be epistemic biases, the issue of which bias is epistemic and which instrumental is an intricate one. Rationality is indeed a multifarious concept, not a single mental quality (Stanovich et al. 2011, p.191). It is not always certain where epistemic rationality and where instrumental rationality is at work, in fact, it is certain that, in daily life, they are used together, in various degrees, for problem solving. Kelly (2003) has even proposed that epistemic rationality is instrumental rationality in the service of one's cognitive and epistemic goals.

During the following discussion of biases, as throughout this article, I am only concerned with what happens with bona fide archaeologists under the pressure of excavation, and who do not accept these biases in a conscious way. I am not discussing what happens during "book writing", when the results of excavations are put together in large syntheses involving regional comparisons etc. For such instances, the time and cognitive resources available to authors are considered, by comparison, unlimited, so biases do not have any adaptive justification, and they have no "desirability" component whatsoever. This particularly holds for "alternative" archaeologies such as the quest for Atlantis or extraterrestrial pyramid builders (Fagan and Feder 2006). Also, it should be said that all archaeological examples given in this article are simplified to convey the point.

Data is hardly ever acquired in modern science by observations that are devoid of particular questions, hypotheses, or theories. One cannot observe "in general", one needs to focus. The need to bring confirmation or refutation to a model underlines most experimental work (such as the speed of chemical reactions at various temperatures). The nature of scientific investigation could be purely observational only if technological means of observing the world, so strong that they would completely break the current scientific paradigm, were suddenly available. Although it is debatable whether a given scientific paradigm can generate the knowledge necessary for creating technology capable of overturning that paradigm, it is conceivable that with (for example) an infinitely powerful microscope we would perhaps not know what else to do but observe.
While before the coming of age of archaeology as a social science most excavations were of an observational nature, attracted by the possibility to uncover monuments and various types of artefacts, with the advent of New Archaeology in the 1960s the need for research design was (at least theoretically) well established. This meant that an excavation needed to test hypotheses, and thereby answer questions about a past community, since simply amassing information about the variations of past material culture was perceived to be meaningless in the absence of a theoretical framework. In order to be sure one will solve any problem by digging up a site, one must first set the problem. However, while one can excavate one of the few unexcavated houses in Pompeii with a rather precise research design, not the same holds for a site that has never been excavated. Archaeological theory generally deals with the fact that the object of inquiry is destroyed in the process by emphasizing that this object is just as much "created" in the process, the long lost meaning of buried site being restituted to society. However, the problem of non-repeatability remains, and impairs our ability to achieve full confidence in the results, or to use them without qualifications in generalizations.[6]

[6] To a certain extent this aspect of the excavation is shared by other investigations in social sciences, especially those that quantify verbal data. What excavation has most strikingly in common with the

It seems appropriate to begin this overview of archaeological biases with the **congruence bia**s (Baron 1994), accounting for scientists' tendency to privilege direct testing of their hypotheses, rather than seeking immediate disconfirmation. For example, in the soil samples from what is thought to be the floor of a metal processing area, one will first look for hammerscales, rather than check them for fish bones. Having found three post holes creating an L shape, one might be more inclined to search carefully for another post hole in the missing corner of the rectangle, rather than try to search in a place with no geometrical logic in the hope that one will find a post hole so awkwardly placed that it will make less likely the hypothesis that these post holes could have been part of the same building. The explanation for this though is not simply naïveté, or a quest for immediate gratification, but a "confirm early, disconfirm late" strategy. This was recognized in Faraday's work by Tweney (1985). In 1831, as part of his discovery of electromagnetic induction, Faraday conducted 135 experiments, the majority of which contradicted his expectations, but were ignored. Indeed, "a confirmation heuristic is one of the highly functional means by which knowledge is made possible." (Tweney and Chitwood 1995: p.255). Remarkably, it happens often in field archaeology that one is only allowed to test once or twice for his hypothesis, which of course is not the case in repeatable experiments. Those tests will certainly look for confirmation, and the reason is that this gives the archaeologists at least one chance that the process will be concluded by understanding, rather than by confusion. By default logic, what is not known to be false will remain true. The way hypotheses are formulated is of paramount importance here. Some hypotheses are what one could call confirmation-effective, in that they gain considerable momentum from receiving partial confirmation, whereas if newly uncovered evidence points in a different direction, this does not immediately invalidate them. For example, our guess is that in this bag with balls of unknown colour there is a majority of red balls. Producing balls that are red considerably strengthens our hypothesis, although it cannot be confirmed until all balls, red and non red, have been counted. Other hypotheses are refutation-effective, in that one single piece of evidence that disconfirms them can establish that they were incorrect, while evidence that supports them will not advance our confidence much. If our hypothesis is, say, that in this bag are only red balls, producing a ball of any other colour from the bag instantly proves our hypothesis to be wrong, but confidence increases little with each successful test. How to formulate hypotheses which can be easily falsifiable and may also obtain substantial support after only little successful testing is a crucial point in the logic of scientific discovery (Nersessian 1992, Thomas 2005, Fogelin 2007).

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scientific experiment is the obligation towards full disclosure. They both need to record, archive and disseminate all evidence retrieved in the process so that they can benefit the professional milieu and the laymen alike (Pavel 2010). Publications of scientific experiments often mention unexplained data that appear to conflict with the final interpretation; archaeological reports, less so.

Related to the congruence bias is the **confirmation bias** (Oswald and Grosjean 2004: pp.79-96), the interpretation of new evidence as confirming preconceptions. Tweney and Chitwood (1995) have proposed that this confirmation bias, far from being a dysfunctional aspect of science (Mahoney 1976) is in fact "a marvelous adaptive characteristic of human thought", as in the Faraday example. The **expectation bias** can also be considered here (Jeng 2006), as it describes the attitude of high sensitivity of the scientist to data that confirm the expectations of the outcome of an experiment, combined with the reluctance to accept data that contradicts these expectations. In economics this is often called **loss aversion** bias. Indeed, while pursuing the excavation with a provisory explanatory model in mind, the data that confirms and enriches it appears to be more "visible", while data that contradicts it is investigated more rigorously for "reliability". In this case, too, we deal with a bias that may be beneficial in the early stages of scientific investigation. Of course it is not proposed here that one should brush aside anything that disconfirms the first glance assessment of a situation. Also compare here the **Semmelweis reflex** – the tendency to reject new evidence that contradicts an established paradigm (Edwards, 1968).

It ought to be stressed that evidence produced by the excavation is less a product of the archaeologist's decisions than is the evidence produced by a chemical experiment the result of the experimenter's decision. It could be said that in archaeology one is allowed to turn cards face up and see what this brings, but one cannot produce what is on the cards. A chemist studying alkynes can follow all the steps of acetylene's synthesis from methane, in order to vary certain control parameters, measure deviations and draw conclusions. The archaeologist studying prehistoric ovens cannot materialize them by an excavation decision, although, in some cases, e.g. - after assessing a geomagnetic map, he may imagine that the presence of an oven is more probable in a certain spot.

The endowment effect (Kahneman et al. 1991 – also known as the **status quo bias**) is generally described in economic studies as people's tendency to ask for much more to give up something they own than they would be willing to give in exchange for it. Confronted with complex data retrieved in the course of the excavation, and under pressure to make decisions as to how to excavate further, archaeologists tend to create rather quickly an explanatory model for it, often based on few clues or not decisive ones. They then require much more substantial evidence in order to abandon or alter that model. One may wonder why one could not entertain several interpretative models at the same time throughout the excavation. The answer is that at some point testing the accuracy of the first model may preempt the possibility to test for the second. Removing soil in a certain way to test for one may make it impossible to remove the soil in a different manner to test for the other. Therefore, given the practical constraints of field work and the computational limitations of the archaeologist it can be argued that this bias is in fact an adaptive heuristic.

The **hyperbolic discounting bias** (Hardman 2009, considered an instrumental bias by Stanovich et al. 2011) comes into play as the stronger preference for more immediate rewards compared to later rewards, more marked with rewards that are closer to the present moment. The urge to acquire certain information (the reward) as soon as possible, in an attempt to put order in an array of conflicting data, is very strong in the field, but ought to be resisted. Establishing the date of this wall by exposing it to assess the construction technique is tempting, although by digging along the wall one destroys its connection to the floors and layers that could have given it a much more reliable dating later on.

As archaeologists are constantly counterposing a historical narrative reconstructed by them with the data gathered to the reality of the trench, they permanently have judgments ready to be confirmed or disconfirmed by new evidence. For example, while excavating a house, one can hypothesize that the Late Roman wall was built reusing Early Roman foundations, which, if it sounds like a convincing conclusion, will tend to lend credibility to any narrative that parsimoniously conduces to it. While this is in fact a biased behaviour (reflecting the so-called **belief bias**, Klauer et al 2000), it also has its heuristic role in effectively advancing series of hypotheses and encouraging concatenation of logical steps in explanation. Archaeologists' conclusions are always partial, tentative, and change with new evidence; they are correct only within the defeasible logic paradigm (Pollock 2008), and not within classical elementary logic. There are many instances, particularly in older excavations, when archaeologists unconsciously manipulate the excavations and interpret the data in order to achieve their expected conclusion. This so-called **observer-expectancy** effect is a type of bias which involves, on the one hand, what the archaeologist thinks the excavation will uncover based on the opinion of respected specialists visiting the excavation, or that of team members (*groupthink*, Janis 1972), on what others have generally found in this type of sites, on previous excavations at this very site etc. On the other hand, it speaks volumes about what the archaeologist would prefer to discover, given her own area of expertise, the research objectives as proposed to the excavation sponsors, the media hype etc. Quite the opposite happens when archaeologists exhibit the **reactance bias** (Brehm and Brehm 1981) in which informal (and occasionally formal) pressure from funding bodies, politicians, or peers towards a certain outcome of the excavation unconsciously pushes the archaeologist towards results at variance with it.

Another clear source of bias in archaeology is **illusory correlation** (Tversky and Kahneman 1974), in which a relationship is forged between stratigraphic events or between artefacts which are in fact unrelated. Constantly trying to make the evidence fit so that there is no fifth wheel left often leads to pairing disjunct entities in an effort to create order - a clean picture. Isolated or atypical walls, which do not seem to belong to any building, are often correlated as part of some peculiar construction phase, one that accounts for all of them as a caught criminal for other unsolved murders. The simple fact that some data, particularly intriguing and unexplained, are sticking out like a sore thumb, and the archaeologist is constantly pondering about them, may lead him to unconsciously correlate them. Another bias related to this is the **clustering illusion** (Gilovich et al. 1985, Kahneman and Tversky 1972) accounting for the perception of patterns where in fact the data has been randomly generated. An example would be the tendency to aggregate post holes in meaningful structures, which is often illusory, and particularly so outside open area excavations. Artefacts surprisingly brought together by natural site formation processes often trigger comments on "ritual behaviour". In any case, as opposed to random sequences, patterned sequences of data are easier to interpret and therefore are more readily identified and recorded. In fact, a random configuration of the soil matrix is hardly described at all beyond saying that it does not exhibit any patterning. Indeed, patterning helps the archaeologist to identify and record for example a disturbance in a well trodden road surface, or backfill material contrasting with more sorted and compacted occupation layers. The presence of patterns in the distribution of artefacts too is generally more indicative of human agency and has a higher cultural relevance than random distributions, which however can still reflect a number of activities such as abandonment or discard processes. By the same token, patterned material culture offers clues as to the continuation of excavation, answers to questions previously asked, provisional confirmation for hypotheses and strength to defeasible conclusions (Pollock 2008, Doerr et al. 2011).

Escalation of commitment (Staw 1976, **or sunk cost bias**, Arkes and Blumer, 1985) is the phenomenon in which one continues investing in a decision, although the decision eventually appears to be erroneous, simply on the basis of how much has already been invested in it. This lost and irrecoverable energy (or money or time) is the sunk cost of the activity. When the interpretative model used by the archaeologist to accommodate the evidence gathered hour by hour has held for a while and answered well to the demands of informational input, the archaeologist will be increasingly reluctant to change it. He might, as we have seen, turn a blind eye to data challenging it and continue to stretch it as much as possible to make room for divergent information. Changing this model would incidentally mean that any number of decisions made on its basis have to be reappraised and the damage done (from missed stratigraphic units to contaminated samples) acknowledged and mitigated. Interestingly, having kept a very detailed written record of the excavation may also become at this point, with hindsight, embarrassing. It is not flattering to have documented, in a variety of forms from context sheets to trench diaries and weekly reports, and perhaps with enthusiasm and wit, a theory now known to be mistaken. However, sticking to a model despite new evidence that the model is jaundiced is one of the most pernicious biases in archaeological decision making.

Cognitive dissonance or (in economy) **post-purchase rationalization** (Festinger 1957; Cohen and Goldberg 1970) is the tendency to persuade oneself that the decision made was correct, and therefore, as another form of commitment bias, is related to the escalation of commitment. Archaeologists are, and indeed should be, constantly engaged in maieutics, arguing the pros and cons of their own decisions with themselves and their colleagues. This is mainly due to the fact that never in the archaeological excavation does all evidence point unanimously in the same direction and a dissimilar interpretation is always possible, albeit with varying probabilities. Once a critical mass of evidence, framed in a certain theory, seems to be well associated with a narrative reconstruction of the events of the site, archaeologists can let themselves be persuaded to make a certain decision regarding the continuation of the excavation. Arguing the pros and cons of every decision is a routine exercise carried over on site which, by rehearsing and weighing reasons, helps to keep interpretations lucid.

I conclude this brief investigation of biases by mentioning **anchoring,** (Tversky and Kahneman 1974, instrumental bias for Stanovich et al. 2011) a well-attested cognitive bias and a typical strategy in the bounded rationality model of fast and frugal heuristics. According to this, we commonly use one prominent piece of information or characteristic to assess a situation involving many more other factors. When it comes to scientific reasoning, the use of such clues to navigate through a sea of heterogeneous evidence is in fact mandatory, the only question being whether they are optimally selected or not. To know which parameter is key in a given array of data is a function of both the experience and creativity of the scientist.

We probably cannot prevent biases from entering archaeological reasoning processes and their results. To the extent to which they help archaeologists be more efficient decision makers, they might compensate for instances when the interpretation of evidence is overdone because of biases. Such instances we should try to forestall by encouraging debate, transparency and interdisciplinarity - including exposing archaeologists to rationality, decision making, and bias literature. We can try to account for what we suspect are our biases, warn the reader against them, and ultimately, as long as our research is conducted with no hidden agenda, not worry about biases (*contra* Faust’s 1984 profoundly pessimistic vision that biases completely clutter scientific reasoning). Occasionally, the right bias can help one find a solution to a problem that can hardly have been solved in an unbiased manner. (Upon which the solution should be tested and proven correct with unbiased procedures!). Some biases bring us closer to the truth, and therefore neutrality is not an epistemic ideal. Biases should not be defined as mistakes of reasoning, as a whole, but as deviations of which some can be empirically proven to be wrong in a certain theoretical framework (Antony 1993). Advancement in the study of biases as heuristics used in archaeological problem solving could be done by sociological means, by questioning a large number of field archaeologists about the way they reason. One could thus attempt to measure rationality errors by quantifying instances where any of the axioms or particular strictures of rational choice is being violated (Stanovich et al 2011). Archaeological final reports are singularly unsuited for this purpose because they typically do away with all contradictions encountered in favour of straightforward conclusions. Each of these conclusions in fact incorporates dozens of partial conclusions, reached by hundreds of small decisions in the field. The alternatives to those decisions cannot possibly be all mentioned in the final report, but they should still be somehow accounted for.

All our knowledge is biased, but the more individuals produce it, the more the personal, idiosyncratic sources of bias will be ironed out in favour of collective socio-cultural bias, less evident, if not less pervasive. The ultimate test of such knowledge is its compatibility with knowledge produced by our contemporaries (Saarikoski 2007).

IV. Features of archaeological reasoning

In the footsteps of Thomas Kuhn, historians and philosophers of science have begun to emphasize scientific knowledge as an actively negotiated social product of human inquiry, and see each society as giving rise to specific knowledge claims (Cozzens and Woodhouse 1995; Saarikoski 2007). Regardless of the moment in history, science was re-cast as a full-fledged socio-cultural activity (Latour and Woolgar 1979, Collins, 1985, Knorr-Cetina 1999). It can be argued that for archaeologists to attempt to construe archaeological evidence independently of their historical context, of their profession's social engagement and other stakeholders' competing interpretations would make them – if not Sen's rational fools – then not much more than cogent oddballs. In Alexander Lovie's view (2004), argumentation in science is always from a point of view – generally, unless one holds a position, one does not take the podium (unless to pass judgment on the scientific stances of others). Furthermore, Lovie establishes the rhetorical nature of scientific reasoning, important parts thereof being necessarily concerned with persuading their audience, composed of other scientists and/or laymen. Lovie emphasizes the context-boundedness of scientific beliefs and practices, and the collective, theoretical and reflexive nature of scientific skills. His conclusions are worth quoting:

> "scientists are sense making, rhetorical beings working within a collectively constructed and dynamically changing context of knowledge, beliefs and actions… ; scientific reasoning consists of both cognitive and rhetorical work and the instrumental manipulation of the material world, all situated within a dynamic and interactive context, with all the parts formed by collective social processes" (*id.*: p. 359)

What model of rationality is best suited to produce such knowledge and reflect the mental processes of the creators of such knowledge? Modern models of rationality have Popper as harbinger, for whom science was no longer a closed game of deductions from a priori truths, but an open game of conjectures and refutations. Popper's model is permeated by "methodological selection", with only the strongest theory surviving repeated testing (Sarkar 1995). In his classical rejection of the possibility of finding laws of scientific discovery, Popper calls them irrational, and states they are caused by some Bergsonian creative intuition. With the role he gives conjectures, he ushers the irrational in science, in what otherwise is still a beautifully poised rational model. Post-modern models have their incipit in Kuhn who, criticizing traditional empiricism and rationalism contended that we need a historically oriented understanding of scientific inquiry as a rational activity, since reason always has socio-historical coordinates. Archaeology cannot make use of Feyerabend's anything goes any more than it can stick exclusively to neo-positivism, and it needs to better define its position in the conceptual space between Popper and Kuhn. Ideally a rationality model would be found that applies to both practical and theoretical rationality, so as to eliminate split rationalities, and the chasm between natural and social sciences, each with its different objectivity (Audi 2001).

The rationality model that appears to be pervasive in field archaeology is a bounded rationality one, and is shaped by fast and frugal heuristics, often in the form of biases. Archaeologists are trying to maximize the subjective expected utility, and in their case utility is a function of knowledge gain. The questions archaeologists ask, and the answers they give, are results of teamwork in a strong cultural and social field in which they construct knowledge, negotiate it with their peers and let it slowly distill in social awareness of past and alterity.

The cognitive processes used in the field showcase different types of non-monotonic logic. As opposed to formal logic, their exercise does not create a jurisprudence of knowledge which is deductively valid and which can be further used for any other gnoseological purposes. On the contrary, in non-monotonic logic, as we have seem, all knowledge is partial, and in fact as data keeps flowing in, knowledge has to be revised. More specifically these are default logic, where for example what is not known to be true is false, and defeasible logic, where plausible tentative conclusions, not deductively valid, are drawn from incomplete and contradictory data and then await confirmation. Indeed, for Pollock (2008: p.452) "no sophisticated cognizer operating in a somewhat unpredictable environment could get by without defeasible reasoning". Such logic is paraconsistent: "pragmatic success gets top priority when it comes to matters of theory choice or paradigm switch", and defines a theory of rationality which is not a priori, but is constrained by the demands of facts (Sarkar 1995). Deductive logic in pure form is in an ancillary position, and is generally reserved for sorting out Harris Matrixes in the post-excavation stage, at a stage when fluid decisions made in the field lose their probabilistic component and are reified into logical truths; defeasible conclusions which have never been refuted are converted into certainties.

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