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Hunting for evidence of cognitive planning: Archaeological signatures versus psychological realities

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ABSTRACT

Cognitive planning is acknowledged as one of the hallmarks of modern cognition. However, identifying objective evidence of cognitive planning in the archaeological record has been difficult and controversial. While some archaeologists have argued that so-called behaviourally "archaic" *Homo sapiens* and *Homo neanderthalensis* were unable to plan, others have proposed that complex material culture could not have been produced without sophisticated planning abilities. There is agreement, however, that evidence for cognitive planning can readily be found in the archaeological record. This review presents an alternative interpretation based on research in psychology, neuropsychology and reinforcement learning. It outlines alternative mechanisms that can drive behaviour including goal-directed actions, habits, hierarchical reinforcement learning and fixed action patterns. We contest current archaeological theory by arguing that: 1) for methodological reasons, evidence for cognitive planning cannot be found in the archaeological record and, 2) basic learning processes, based on contingency and contiguity, are powerful enough to be the building blocks of substantially more complex behaviours including the acquisition and "invention" of technological behaviours. We suggest that cognitive archaeology focus on collaborative projects to empirically test existing theories utilising techniques such as neuroimaging, dual-task paradigms and mathematical modelling. Such experiments would greatly improve the concordance of archaeological theories with those of allied disciplines.

Contents

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1. Introduction

A central assumption of Palaeolithic archaeology is that evidence for cognitive evolution can be readily obtained through the investigation of stone tools (e.g. Gowlett, 1979; Holloway, 1969; Wynn, 1985, 2002). One branch of this research aims to identify evidence for cognitive planning, a unique human adaptation acknowledged as one of the evolutionary hallmarks of modern cognition (e.g. McBrearty and Brooks, 2000; Mellars and Stringer, 1989; Noble and Davidson, 1996; but see Binford, 1985; Shick, 1987). Cognitive planning involves the mental exploration of logical consequences of an individual's behaviour with the intention of deciding on the most favourable course of action among a number of alternatives (Owen, 1997). Identifying definitive evidence of planning in the archaeological record has, however, been difficult and controversial.

A number of archaeologically relevant behaviours have been claimed to show evidence of planning: for example, the production of complex technology, seasonal exploitation of resources and the transportation of exotic materials (e.g. Ambrose, 2010; Coolidge and Wynn, 2001; Kuhn, 1992; McBrearty and Brooks, 2000; Mellars and Stringer, 1989; Noble and Davidson, 1996; Reuland, 2010; Thieme, 1997; Wadley, 2010a; Wynn and Coolidge, 2010). However, it remains unclear whether planning was a prerequisite for these behaviours, or whether the observed archaeological trends could be due to other cognitive factors such as differences in executive attention (Beaman, 2010) or working-memory (Coolidge and Wynn, 2004); although, the degree to which these processes can be considered independent and distinct from planning is also questionable.

A widely discussed example of differences in planning abilities centres on the apparent simplicity of European Middle Palaeolithic (MP) and African Middle Stone Age (MSA) technologies compared with more complex Upper Palaeolithic (UP) and Later Stone Age (LSA) technologies. Although recognised as specifically distinct from *Homo neanderthalensis*, MSA humans have been sometimes been referred to as “archaic” *Homo sapiens*, as their behaviour purportedly differs from that of UP/LSA “modern” *H. sapiens*. Some authors have argued that the behavioural differences between MP/MSA and UP/LSA populations are most likely due to limited cognitive capabilities of “archaic” *H. sapiens* and *H. neanderthalensis*, including a restricted ability to plan (e.g. Klein, 1995; Wynn and Coolidge, 2008). Others have accounted for differences between archaeological industries using social explanations, such as differences in division of labour (Kuhn and Stiner, 2006) or cultural trends (Bar-Yosef, 1998). A third point of view has argued that behaviours which are present in both MP/MSA and UP/LSA assemblages, such as the seasonal exploitation of resources and the manufacture of multi-component weapons, required sophisticated planning abilities (e.g. Ambrose, 2010; Haidle, 2010; McBrearty and Brooks, 2000; Wadley, 2010a). Thus, the differences between assemblages are argued not due to cognitive differences and therefore must result from another factor, such as geographic isolation and differences in population density (McBrearty and Brooks, 2000).

However, before we can assess which of these hypotheses offers the most plausible explanation, we believe that a simpler question needs to be asked: *Is cognitive planning necessary to produce the archaeological assemblages characterising the UP and LSA*?

The aims of the present review are 1) to provide an overview of what is known about the psychology and neurobiology of planning, goal-directed behaviour and stimulus–response learning, 2) to summarise the types of behaviours that each of these systems support and 3) to relate this information back to the archaeological record to infer the minimal cognitive abilities required to produce archaeologically relevant behaviours. In doing so, we will provide an outline of the neural mechanisms known to support planned versus goal-directed versus routine behaviours in animals and living humans, and will outline how these mechanisms relate to the question of identifying the cognitive mechanisms underpinning variation in complexity of behaviour during the Palaeolithic. Our ultimate goal is to assess whether a difference in planning ability offers the best explanation for the technological complexity of modern human behaviour or whether the results of experimental psychology provide a more parsimonious explanation.

2. Planning

The difficulties in trying to identify archaeological signatures of planning arise in part from a lack of informative definitions and testable hypotheses. For example, Kuhn (1992, p. 187) defined planning as “*any* technological act that fills needs occurring some time after its execution”. Although it was noted that “…apparently “forward-looking” behaviours are manifested by a number of animals with minimal capacities to actually conceptualise the future”, this information does not assist a researcher to objectively test whether or not an animal has the capacity for planning as no further distinction was made between the cognitive or neurological processes involved in “*apparently* forward-looking behaviours” (emphasis added) as opposed to actual planning. Nor were any criteria offered which would allow for objective classification of observed behaviours. As such, the researcher is at liberty to impose their own beliefs about which animals do and do not have the capacity to conceptualise the future and then pass judgement accordingly.

To illustrate, suppose a researcher observes a crow dropping a stone near the source of its food. Two days later, the crow is observed using this same stone to crack open nuts. Without any further information about the cognitive capacity of crows, this behaviour would satisfy Kuhn's definition of planning because the animal has engaged with an object in a way that satisfied a future need. However, the conclusion that “Middle Paleolithic hominids were only able to plan from one day to the next” (Kuhn, 1992, p. 194) would ascribe greater planning abilities to crows rather than Neandertals. A definition such as this does not allow a researcher to objectively test assumptions of planning ability because it is this assumption that forms the basis of the qualifying statement (i.e. does the animal have the capacity to plan?). This definition also fails to acknowledge that, despite the vast majority of humans having the capacity for planning, normal human behaviour is not always planned. If an adult human had dropped a stone near the source of nuts and then used this tool to acquire food two days later, how could an experimenter objectively determine whether or not the behaviour was planned? The human may have the capacity to plan but how could an experimenter determine whether or not this cognitive ability was actually used to perform the behaviour? This situation becomes more troublesome still when the planning ability of the person in question is unknown, as is the case with extinct hominins.

It is for these reasons that archaeological definitions of planning need to be revised as simply observing a technological behaviour that satisfies a future need does not provide any information as to whether it resulted from planning in anticipation of use, through discard following use, as a result of associative learning processes (as will be explained further) or serendipity.

There are three underlying causes which could produce a behaviour that, to an observer, may appear to have been planned: 1) when a problem is complex and novel, the correct solution is unknown and the solution is thought through prior to negotiating the problem, 2) when a problem is complex and novel and the correct solution is unknown but the solution is explored through trial and error, and 3) when a problem is complex but has been encountered many times previously so that the correct solution is known and skilfully implemented. Although, the observed behaviours produced by each of these three situations may appear identical, the cognitive processes driving the behaviour cannot be determined observationally because an experimenter has no information about whether or not the agent (i.e. human, animal, robot, computer program or algorithm) has encountered the problem before, nor can they obtain information about the agent's thought process simply through observation. While the term “planning” has used to describe