

## **Abstract**

### *The Design Space of Lithic Technology*

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In this thesis I develop a theoretical model of lithic design space based on the engineering principles of stone reduction. I first explore previous researchers' views about knapping as a combination of 'gestures'. I conclude that an overt focus on stone tool typologies as a framework for inferences undermined these efforts. A way ahead is to use the mechanical constraints of lithic design space as the framework for inferences. I next explore mechanical constraints from two perspectives: those observations made by laboratory experimentalists about the physical laws that control stone fracture, and statements by knappers about how they combine body kinaesthetics with fracture mechanics to achieve effects. Contradictions in these perspectives are reconciled by deconstructing knapping 'know-how' in terms of the experimental literature. From this I identify five knapping variables—divided into seven aspects—that produce archaeologically visible byproducts. I subdivide these variables/aspects into subcategories based on a scale of increasing technical complexity. I then create a design space model by organising the subdivisions in a ten-column matrix.

I next turn to the epistemological and practical issues of inferring knapping behaviour from its archaeologically visible byproducts, and conclude that reduction sequence analysis is the best analytical method for supplying the necessary reconstructions. I demonstrate the efficacy of the method through analysis of an assemblage from Liang Bua Cave, Flores, Indonesia, and I score the Liang Bua reduction sequence according to the design space model. I do the same for 28 other reduction sequences in the literature and discover that design space scores do not always support assumptions about technical complexity, particularly for early hominin assemblages. For example, Late Acheulean handaxe manufacture scores higher than Levallois core reduction, an inversion of the standard story of technological evolution.

The design space model assigns scores to reduction sequences, but differences in scores are themselves contingent on structural principles behind the way that the removal of individual flakes is organised. I next show how ideational and action elements of knapping are organized into a structural 'unit' to remove flakes by freehand percussion. The 'basic flake unit' involves recognising an appropriate geometrical relationship between the platform and core face and articulating actions to remove the flake. The 'complex flake unit' is two-tier and involves creating an appropriate geometrical relationship by anticipatory flaking, using basic flake units, before removing an objective flake. A complex flake unit is 'elaborated' by adding a second branch on the lower tier for platform grinding.

The architecture of knapping refers to the ways that units are linked to create an effect. This is done using a simple two-step algorithm, 'identify high mass → apply the flake unit'. The simplest way to link units is serially. In this case, the knapping process essentially begins anew with each flake removed. In 'higher order architecture', units are combined in interlocking tiers. Reduction at one tier is done to condition reduction at higher tiers. Studies in developmental psychology show that

modern human children achieve higher order architecture between 24 and 36 months. Chimpanzees are incapable of consistent higher order architecture.

I next apply this framework to early stone artefact assemblages and offer an alternative scenario of the early evolution of stone flaking technology. For example, higher order architecture is absent from the putatively 'sophisticated' Levallois technique: Levallois reduction consists of simple chains of units linked by the flaking algorithm. Late Acheulean techniques of reduction share a similar simple architecture with Levallois; however, the Late Acheulean design space score is higher than Levallois because of the greater complexity of the flake unit applied in the Late Acheulean. Technological change in the Lower and Middle Pleistocene involved tinkering with flake units, but knapping architecture was not elaborated beyond simple chaining together of flake units. This highlights the power of unit chaining by the simple flake algorithm to create seemingly complex structures that mimic intentional design. True higher order architecture is not apparent in the archaeological record prior to the appearance of modern *Homo sapiens*.

Design space analysis is a new way of thinking about stone tools, one that moves away from ambiguous arguments about tool form and instead explores the ways that humans generate form from stone. Design space analysis grounds inferences about stone knapping in the physical laws of fracture and provides a holistic context for exploring humankind's earliest technological process.