Cognitive Load and Human Decision, or,

Three Ways of Rolling the Rock Up Hill

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I Foragers' Dilemmas and Bargaining Games

Human life is one long decision tree. Fortunately, some of these decisions are not especially challenging. Identifying local mores about dress is often very important, for individual fitness often depends on conformity to local norms. Once others are in business suits, it is harder to be treated seriously while dressed in a T-shirt and jeans. But the task does not seem intrinsically difficult. It is reasonable to suppose that most dress codes could be learned by inductive generalisation from primary social experience (plus or minus a bit). Appearances might mislead, for we lack well-developed theories of the power of learning. But with respect to most clothing norms there is no plausible version of a poverty of the stimulus argument[1]. Some important decision problems have a low "cognitive load": there is no particular problem in explaining how intelligent agents could acquire and/or use the relevant information.

However, discovering the local dress code is not typical of human decision making. Human action often depends on information that is hard to acquire, hard to use, or both. This view has become somewhat controversial with the articulation of a program for explaining human decision making on the basis of "fast and frugal" heuristics. The defenders of this program think that we can normally make good, though not perfect decisions, by following simple rules and exploiting small amounts of easily available information. Thus, instead of weighting all the factors necessary for making an optimal decision in choosing a car, we normally get a good result by using a "take the best" heuristic, allowing one criterion to dominate our choice (Gigerenzer, Todd et al. 1999; Gigerenzer and Selton 2001). But this approach is not plausible as a general picture of human cognition. For stock examples abstract away from a key feature of human life, namely epistemic pollution. Other decision makers degrade our epistemic environment by active and passive deception, and such tactics can be counted only by sensitivity to a wider range of information.

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[1] There is the usual implausible version from the lack of explicit negative instruction: when growing up in Australia, I was never explicitly told not to go to school with a dead turkey stuffed over my head. Even so, as Fiona Cowie notes, this would be a fragile basis for positing an innate schema specifying the class of possible clothing norms (Cowie 1998).

There is something right about this program, for heuristic decision making is doubtless central to human life. We often act under time pressure and with incomplete information. So we need decision making strategies that will satisfice under such circumstances, but those heuristics will often be quite informationally demanding. Consider, for example, the problem of gathering resources in a forager's world. This problem is crucial to fitness. Foragers do not accumulate a surplus and often live close to the edge: they must typically make good decisions. Yet consider the intellectual challenge faced by a forager on a hunting expedition who sees an armadillo disappearing down its burrow. Should he try to dig it out, or try his luck further down the path? The optimal choice depends on subtle ecological, informational, and risk-assessment issues. The forager must consider the probability of catching the animal. Is the burrow likely to end under a large rock or other immovable obstacle? He must estimate the costs of catching the animal, including the risks, for some menu items are decidedly dangerous. Costs include opportunity costs. If it will take the rest of the day to dig the armadillo out, the forager has forgone the potential reward of a day's hunting. Finally, of course, he must factor in the benefits of catching the animal. As it turns out, armadillos vary in their value across the seasons. They are much fatter in certain seasons than others ((Shennan 2002) p147). Moreover, there are social complications in the assessment of return, for in many cultures, large catches are shared but small catches are individual property. So forager decision making has a high information load. The right armadillo choice requires detailed knowledge of local natural history and local geography. It requires a clear-sighted assessment by the agent of his own technical skills and social location. To understand forager decision making, we need to understand how this information is acquired and used.

Social decision making, too, has a high information load. Trade is an ancient feature of human life (Ofek 2001). Hence so is bargaining. Yet it has both a high information load and a low tolerance of error. If you try to drive too hard a bargain, you will end up with no deal at all. If you are too soft, you will never make a good deal. Yet deals are not easy to evaluate. You need to evaluate your personal circumstances, and to integrate that evaluation with information about the local availability of goods. What do you want and what you are willing to give up? Will you trade a lower price against slower delivery, or a reduction in insurance cover? If you regularly trade, you

will also need to factor in future effects. These include effects on your reputation and on future negotiations with this agent. Finally, and importantly, the micro-management of negotiation is important. It is important how you phrase and present your offer[2] . Consider this dialogue (assuming the cart is worth roughly $75 to both A and B):

> A: I would like to buy your cart. I'll give you fifty for it.
> B: No way, A hundred is my absolute minimum!
> A: Alright then, why don't we split the difference and settle at $75?

A has blundered, and will probably now either have to settle for more than $75 or break off negotiations. That is true despite the fact that his offer is realistic. But having made it with his first counter-offer, A will now find it difficult to maintain that position. It is now probable that either negotiations will finish around the $85-$90 mark, or break down when A refuses to move.

These examples are typical rather than exceptional. Human decision making often has a high information load, for we depend on knowledge-intensive methods of extracting resources from our worlds. Our ecological style contrasts with our closest living relatives, the chimp species. For while they engage in some knowledge-intensive foraging, most of their diet is based on fruit and other ready-to-use resources. In contrast, even the simplest foraging lifeways depend on technology and on detailed local knowledge (Hill and Kaplan 1999; Kaplan, Hill et al. 2000) (Henrich and McElreath 2003). Moreover human social worlds are complex, demanding and only partly co-operative. They are complexly structured: divided by gender, status, occupation, generation. They are operationally complex: much human action requires co-ordination with others. And they are complex in their resource demands: successful human life requires access to a large range of goods, not just a few. For this reason human culture adds to the problem of explaining adaptive human action. Human cultures generate a large measure of the informational load on human decision.

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[2] I am indebted here to my student Christo Fogelberg, who alerted me to the value of this example as a

II Three Evolutionary Responses to High Cognitive Loads

High-load problems are typical of human life. They are also ancient. The distinctive features of human cultural life originate hundreds of thousands of years ago; some may be much older (Wrangham, Jones et al. 1999). These features include diverse and regionally differentiating technologies; trade; ecological expansion; and even public representation (McBrearty and Brooks 2000). There has been time for evolutionary responses to these informational burdens: responses that vary according to the stability of the informational demands on adaptive action. Some human problems are informationally demanding, but the information need for good decisions is stable, constant over evolutionarily significant time-frames. In other cases, the information needed for adaptive choice is stable over generations but not hundreds of generations. In yet others, the relevant features of the environment change still faster.

There is a standard conception of the interplay between learning and the rate of evolutionary change. Slow environmental change (or no change) selects for innately encoding the information agents need. For information-hungry skills are then protected against the vagaries of individual learning environments. If the environment changes over generational time frames, there is selection for social learning. Agents that learn from others that bears are dangerous and that salmon are nutritious avoid the costs of trial and error learning, and those costs can be very high. If environments change within the life of a single generation, then there is selection for individual learning, for the beliefs of others are likely to be out of date (Boyd and Richerson 1996; Laland 2001; Richerson, Boyd et al. 2001). I think this picture of the evolution of learning in social animals is broadly right and applicable to our descent, for all three time scales are important in human life. However, the extent of informational demand on human action introduces novel elements to our evolution.

Evolutionary psychology has emphasised the first of these responses, in defending modular conceptions of human cognitive organization. Modularity, I shall argue, goes with predictability and environmental stability. Hence modules — innate, domain-specific cognitive specialisations — play a real but limited role in human response to

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whole, and especially to importance of expertly managing the initial offer and counter-offer.

high cognitive loads. Social learning, likewise, is important, but not for the reason standardly given, namely, to avoid the costs of individual learning (Boyd and Richerson 1996). For human learning is very often <u>hybrid learning</u>: it is socially-structured, environmentally scaffolded trial and error learning. No-one learns foraging skills just by watching and listening to the experts, and precious few learn them without these social inputs. In acquiring, for example, the skills involved in using tools, imitation, instruction and correction are combined with practice and exploration. This is no accident, for hybrid learning, I shall argue, is more powerful, more faithful and more reliable than either pure social learning or unscaffolded trial and error learning (see also (Sterelny forthcoming-a)). Finally, human individual learning is distinctive not just in often relying on social scaffolding; it is also dependent on epistemic technology. Humans make tools for learning and thinking, and these tools vastly extend our cognitive powers. The role of epistemic technology in human thought is the central theme of the recent work of Dan Dennett and Andy Clark. They are onto something very important. But in contrast to Clark (in particular) I shall argue that the use of epistemic technology is itself a high load problem. Epistemic technology makes us smarter than we would otherwise be. But we had to become much smarter to use this technology. So my picture of human response to cognitive load borrows from evolutionary psychology, narrowly defined; from the theory of cultural evolution developed by Richardson, Boyd and their co-workers; and from extended-mind conceptions of Dennett and Clark. But it is importantly different from all of those views.

In the rest of this section I will briefly sketch the three response: the three strategies for responding to high load problems. In section III I discuss the modular strategy in a little more detail, and in section IV social learning. I spend most time on epistemic technology, in section V. For in my previous work I have underplayed the significance of this response to high cognitive load problems in fast-changing environments.

Human response to high load problems does sometimes depend on an innately structured module. Language is genuinely typical of one class of problems humans face. Linguistic competence is critical for fitness. The acquisition (and perhaps the

use) of language is intrinsically difficult. But the organisational features of language may well be stable. Though language is a complex and subtle system of representation and communication, the information a language learner needs to master is restricted in kind and is stable. An innate module is a candidate solution to problems of this class, perhaps evolving via some Baldwin-like process. Some early proto-language was invented, and it spread through general learning capacities of some kind. But its invention changed the selective landscape as these communicative abilities became increasingly central to fitness. Thus the acquisition process became increasingly buffered from vagaries in environmental input as the system itself became increasingly powerful[3].

Capacities that are phenomenologically akin to innate modules can be the result of socially-mediated learning. For we can learn to develop and to automatise quite cognitively demanding skills. A good chess player can make a good, though not perfect, move on the spot. An expert bridge player can count the cards without conscious effort or intervention. These skills take a lot of learning, but once learned, they are enduring and effective. And they reveal one mechanism by which we respond to features of our environment that change at intermediate rates. We reliably develop automatised skills as a result of prolonged immersion in highly structured developmental environments. The forager's dilemma is solved by such skills (see e.g. (Diamond and Bishop 1999)). The local ecology of a foraging people is fairly stable. But it does change. People move, and that changes the ecology, geography and natural history of their immediate surroundings. Moreover, many aspects of local habitat change over time, both through the impact of humans themselves, and through extrinsic causes, especially those to do with climate. So the resource profile of a local area mostly changes at intermediate rates. Yet if agents are to make good decisions, that profile must be tracked accurately and used appropriately. In their overview of theories of cultural evolution Joseph Henrich and Richard McElreath illustrate this point with a very vivid example. The Bourke and Wills expedition was an attempt to explore some of the arid areas of inland Australia that ended in failure and death. Local aboriginal people survived without undue difficulty in the area that killed the expedition, because survival depended on accumulated local knowledge. The locals

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[3] For a plausible though of course speculative picture of the stages through which a crude proto-

had learned how detoxify locally available seeds from which bread could be made, and they had learned how to catch the local fish. Fatally, the members of the expedition had no such information (Henrich and McElreath 2003).

Intermediate rates of change do indeed select for social learning, yet the cognitive burden of adaptive foraging decisions is carried by social learning of a very special kind: automatised skills acquired in learning environments which are adapted to induce the reliable acquisition of those very skills. As Diamond notes in his account of the natural history skills of Papuan foragers, the acquisition of skill is neither a process of pure instruction nor of unstructured exploration (Diamond and Bishop 1999). Social learning of this kind is a special case of an important evolutionary phenomenon: niche construction. Many animals alter their environment as well as adapting to it, for example by building burrows, nests and other shelters. They partially construct their own niches (Odling-Smee 1994; Laland and Odling-Smee 2000; Laland, Odling-Smee et al. 2000; Odling-Smee, Laland et al. 2003). Humans are extreme examples of niche constructors. Furthermore, their niche construction takes two very special forms. It is downstream and cumulative: members of generation N engineer not just their own environment but also that of the N+1 generation. Moreover, generation N+1 inherits the effects of generation N, further changes the environment and those further changes become the world into which generation N+2 is born and grows. Second, this niche construction is often epistemic. Humans engineer their own informational world and that of their descendants, transforming the informational character of the problems they must solve. For example, the invention of psychological vocabulary makes the fact that others think differently from you much more salient. The non-linguistic behaviour of other agents can show that their beliefs and preferences are unlike your own. But once others learn to talk about what they think, they attempt to cajole and persuade; and differences in perspective become inescapable. The reliable acquisition of skill is often the result of this transformation of downstream developmental environments.

Evolutionary psychologists are rightly struck by the fact that humans all over the world reliably acquire difficult competences despite the differences in their personal

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language may have been elaborated, see (Jackendoff 1999).

circumstances. This acquisition process must be <u>entrenched</u>. It is buffered against the vagaries of individual learning histories. Sometimes, though, this buffering is by environmental engineering. One crucial chunk of the foraging tool kit is a natural history taxonomy, and it turns out that in forager cultures such taxonomies are extensive and in some respects remarkable accurate. In particular, the <u>species category</u> turns out to be a universal and central element of forager natural history taxonomies, and this is the basis of Atran's argument that we have innate natural history modules (Atran 1990; Atran 1998). My own view is that forager taxonomy is a consequence of the intersection of (i) inherited perceptual tuning, (ii) objective features of the biological world — for species are objective units in nature — and (iii) engineering developmental environments (see (Sterelny 2003)). The acquisition of folk biology is scaffolded by apprentice learning. As children accompany adults, adult behaviour directs them to salient differences and identifying characteristics of the taxa they encounter. It depends on cultural representations. Pictures and other enduring representations are obviously very important for contemporary western cultures. But pre-literate cultures have and pass on the system of nomenclature they have assembled over time, and this labels differences, making them more salient. Moreover, the process is perceptually scaffolded. Our perceptual input systems are specially adapted to features of the world important for folk biology. Thus these learning mechanisms form a complex hybrid. We are perceptually pre-adapted to notice the relevant features of the natural environment. Forager children are richly and interactively exposed to that environment. But they are exposed to it in ways structured by their communities activities, nomenclature and lore (and perhaps by active teaching as well). This combination of perceptual tuning, individual exploration and social scaffolding makes learning much more reliable than it would otherwise be: notice the failure of the highly experienced, bush-hardened members of the Bourke and Wills expedition to reach survival threshold by individual learning.

In (Sterelny 2003), I focused on the idea that scaffolding developmental environments offers an alternative to modular solutions of the problem of information load. Downstream epistemic engineering can scaffold the development of automatised, highly tuned quasi-modular cognitive skills. I argued that we often needed an alternative to such solutions, for the computational advantages of modularity depend

on environments being informationally stable over evolutionarily significant periods. Innate structuring obviates or reduces the learning problem. Encapsulation eases the computational burden on decision by reducing the size of the data base to be scanned and by allowing a module to be optimised for processing particular kinds of data. Both innate structuring and encapsulation bet on stability. Yet many domains are not stable. Richard Potts has argued that humans evolved in times of increasing environmental instability ((Potts 1996); see also (Calvin 2002)). Even if we had stayed put, our world would have changed around us. But of course, we have not stayed put, and the effects of migration have to be added to those of climate change. Moreover, we induce changes in our own environment through niche construction. We rebuild our own worlds economically, biologically, technologically and socially.

In developing this argument, I underplayed the problem of fast change, and hence underplayed an important aspect of human niche construction. Humans make cognitive tools: we technologically enhance the capacities of our naked brains. Dan Dennett and Andy Clark have recently been pressing this point[4]. To take the simplest of examples, the practice of marking a trail while walking in the bush converts a difficult memory problem into a simple perceptual problem. Along similar lines, Dan Dennett points to the epistemic utility of linguistic labels: if you see that two apparently identical birds are given different names by those around you (say: "buff-rumped thornbill" and "striated thornbill") you are thereby cued to the existence of a difference you would otherwise almost certainly miss. Dennett and Clark are onto something important. But my take on cognitive technology is different from that of Clark (especially). He thinks it explains how it can be that we are much more intelligent than the chimps without our brains being dramatically reconfigured. In contrast, in section V, I shall argue that the use of such technology depends on a very substantial neural upgrade (see also (Sterelny forthcoming-b)).

III Cognition on the Baldwin Plan

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[4] For Dennett's work on these themes, see especially (Dennett 1993; Dennett 1995; Dennett 1996; Dennett 2000) For Andy Clark's, see (Clark and Chambers 1998; Clark 1999; Clark 2001; Clark 2002; Clark 2003; Clark forthcoming)

Evolved, innate modules play a role in the explanation of human response to high cognitive load problems. Language is very likely subserved by such a module, and our "naive physics" skills are likely to be too. The standard case for the modularity of language turns on the difficulty of seeing how language could be learned. This case for innateness is certainly plausible (though see (Cowie 1998)). There does seem to be a large gap between primary linguistic experience and the principles a competent speaker has mastered. Moreover, with other cognitive competences but not language, language itself is available as a learning tool. Notice, though, the connection between innateness and environmental stability. Innately encoding the general features of language by building in some form of universal grammar stabilises this feature of the human environment. Once Baldwin-like evolutionary processes developmentally entrench features of language, deviant forms will be penalised. There is no "temptation to defect" from the phonology, syntax and morphology of your local community[5]. Mutants with a variant form of the grammar (even if that variant would be superior if it were common) will be punished because, presumably, they will find it harder to acquire the language of their local community. But as importantly, <u>language use</u> also makes a modular hypothesis attractive. The information we need to decode speech is a small and predictable subset of the total informational resources of an agent.

Suppose Two Aardvarks hears Old Bear say:

Hairy Max gave Spotted Hyena the spear.

To understand the utterance of Old Bear, Two Aardvarks must identify the organisational features of the utterance: its segmentation into words and phrases, and the overall organisation of those constituents. Sentences must be identified and parsed. A computational mechanism using restricted but especially relevant information could accurately and efficiently parse sentences. For the relevant information is predictable. The general organisational features of language may well be a stable target onto which an evolved, innately structured mechanism can lock. However, to make it worth his while to listen to Old Bear, Two Aardvarks must do

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[5] Except perhaps for the minor ways which serve to badge subcultures within a culture (Dunbar 1999)

more than recover the structural skeleton of Old Bear's utterances. He has to lock onto the semantics of those utterances. He has to understand that Old Bear is conveying news about a spear, Hairy Max, and Spotted Hyena. There is great controversy about the nature of the cognitive demands these tasks impose on Two Aardvarks. But however that controversy is resolved, it is likely that much of the relevant information is predictable. If Old Bear has intends to convey news about spears, he will standardly execute that intention using the term "spear", and a special purpose data base can be set up incorporating that regularity. The specific term for a spear is an accidental feature of this linguistic community. But the existence of terms for artefacts and the practice of communicating about artefacts by using those terms is not. Whatever the nature of symbolic reference, the existence of lexical items of this class is a stable feature of human environments.

In short, an module exploiting a restricted, special purpose data base whose contents — in general or in detail — can remain constant over the generations could probably solve the parsing problem. But this depends on two special facts about language. First, the organisational aspects of language are not tightly tied to other aspects of cognition. It is quite likely that there has been a spectacular flowering in our causal and technical reasoning about our physical environment in the last 100, 000 years. Such a flowering, presumably, has lead to a considerable coinage of new vocabulary. But not to new kinds of vocabulary. Moreover, that coinage leaves the organisational features of language intact. Those features are content-neutral. In virtue of this neutrality, cognitive change in our lineage can be cordoned off from the organisational features of language, and that allows these features to be stable.

Second, in one crucial respect there is no evolutionary conflict of interest between speaker and listener. Whatever the long-term aims of speaker and audience, it is in the interests of the speaker to have his utterance parsed properly, and to have his sentences understood; understood in the minimal sense that Two Aardvarks understands that Old Bear is talking about spears and about Spotted Hyena. In identifying structure and topic there is no arms race between deceptive signalling and vigilant unmasking — unmasking which might require all the informational resources of the audience. Where there is no temptation to deceive, co-evolutionary interactions

will tend to make the environment more transparent and the detection task less informationally demanding. The same is not true of Old Bear's overall plans, and hence it is not true of the pragmatics of language. His desire to persuade Two Aardvarks to go on a wild elephant hunt might well be subverted by Two Aardvarks recognition of that further intention. A modular solution to the informational load imposed by language is plausible because important features of language are stable, and that stability is no accident. It is a coevolutionary achievement, depending on specific features of language and of communication.

IV Niche Construction: Engineering Developmental Environments

In a recent paper on the coevolution of our mental architecture and our interpretative capacities, Peter Godfrey-Smith sketches out one scenario that he thinks naturally leads to the expectation of an innate folk psychology. He pictures interpretation as beginning in a hominid population that has evolved enough behavioural complexity for the prediction of behaviour to be difficult. Some individuals, though, are able to develop a simple framework to predict the action of other agents. This achievement gradually changes the social environment. Interpretative capacities that were initially advantageous but patchily distributed through the population come to be mandatory for effective social life. So there is selection on that population for more reliable and accurate development of this predictive framework. Development is accelerated and canalised, increasingly decoupled from signals from the environment (Godfrey-Smith 2002).

A quite different possibility emerges once we build into our evolutionary scenario the full human propensity for engineering our own environments. Selection for interpretative skills could lead to selection for actions which scaffold the development of the interpretative capacities, rebuilding the epistemic environment of the developing agent. Moreover, folk psychology does not have to be built from scratch. We are likely to have perceptual systems tuned to facial expression; signs of affect in voice, posture and movement; the behavioural signatures which distinguish between intentional and accidental action, and the like. These systems make the right aspects of behaviour, voice, posture and facial expression salient to us. Moreover, these

perceptual adaptations come to operate in a developmental environment that is the product of cumulative epistemic engineering, engineering which scaffolds the acquisition of interpretative skills.

Even so, mental states are unobservable causes of behaviour. So the task of learning folk psychology might seem especially difficult, depending as it does on an inference from effects to their hidden causes (Scholl and Leslie 1999). In adults, the connection between psychological state and action can be very complex and indirect, and that may reinforce the suspicion that folk psychology must be largely innate. But the step from effect to hidden cause may itself be scaffolded. When children interact with their peers, the connections between desire, emotion and action will often be very direct. Moreover, introspection might play a role in suggesting the hypothesis that others have mental states analogous to ones' own[6]. As children mature, they learn to inhibit impulses, and their actions become much more sensitive to spatio-temporally displaced information and motivation. But when interacting with their peers, the inference from effect to cause will often be much less challenging. Children are less good at concealing overt signs of their emotion than adults, and less good at resisting the urge to act on those emotions. With four year olds (as I can testify), the behavioural regularity that links overt desire for an object in the immediate vicinity with an attempt to take possession of that object is close to exceptionless. As three and four year olds are making crucial developmental transitions, the lack of inhibition of their peers simplifies their epistemic environment.

As I see it, then, the acquisition of folk psychology, like that of folk biology, is a hybrid learning process. It depends on perceptual pre-adaptation, individual exploration and a socially structured learning environment. In particular, the reliable development of interpretive capacities is supported by the following factors.

> (i) Perceptual mechanisms make crucial clues of agents' intentions salient to us. Folk psychology is scaffolded by perceptual tuning.

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[6] Recently it has been the received view of developmental psychology that knowledge of first person and third person mental states develop in parallel, so first person knowledge could not scaffold third person knowledge. Nichols and Stich, however, have recently pointed out that the case for complete parallelism is far from clear; (Nichols and Stich 2003)

(ii) Children live in an environment soaked not just by behaviourally complex agents, but with agents interpreting one another. They are exposed both to third party interpretation, and to others interpreting them. Much of this interpretation is linguistic but there are also contingent interactions in which one is treated as an agent: imitation games, joint attention, joint play (see for example (Tomasello 1999)).

(iii) Learning is scaffolded by particular cultural inventions: for example, narrative stories are full of simplified and explicit interpretative examples.

(iv) There are folk psychological analogues of Motherese. Parents who interact with small children often rehearse interpretations of both their own and the infant's actions

(v) Language scaffolds the acquisition of interpretative capacities by supplying a pre-made set of interpretative tools. Thus linguistic labels help make differences salient.

(vi) Interpretation is scaffolded by interacting with agents — your developing peers — who have not yet gained the abilities to mask their emotions, inhibit their desires and suppress their beliefs. Such agents simplify the problem of inferring from action to its psychological root.

Thus a cognitive task which might once have been very difficult, or achievable only at low levels of precision, can be ratcheted both to greater levels of precision, and to earlier and more uniform mastery, by incremental environmental engineering. Like Alison Gopnik, but for very different reasons, I think something science-like is going on as children acquire folk psychology. Science genuinely does trade in theories, and these really do pose a poverty of the stimulus problem. The gap between experience and scientific theory can be crossed only if individual environments are very extensively epistemically engineered: only by the social organization and working traditions of science. In acquiring folk psychology, and in contrast to many scientific domains, we are psychologically tuned to the right features of the world. So acquiring it is a less intimidating problem. Children do not have to be scientists — to be wired into those very special environments — to solve this discovery problem. They need only the help of rather more modest epistemic engineering. Something somewhat science-like is going on in the development of our interpretative capacities. But it is not the operation of especially powerful autonomous learning mechanisms within individual agents; rather our environments have been epistemically engineered in ways that circumvent the cognitive limits of individuals on their own.

To sum up the argument: we do not have to appeal to innate and canalised development to explain the early and uniform development of fast, unreflective, powerful and accurate cognitive mechanisms. We have a second model: automatised skills, and it is easy to overlook their cognitive power. By the time they were 12, the Polgar sisters were of international master class, and improving. Their chess competence was acquired early. It was fast, powerful, domain-specific, often unreflective. However, the sisters did not acquire their chess competence by unstructured trial and error learning. Rather, those skills were acquired in a highly structured, chess-soaked developmental environment. A behavioural competence that might seem to be the signature of an innate module can be produced by a highly structured developmental environment. Of course, chess is not a perfect model of folk psychology, for chess is not a field of hidden causes. Even so, it is a model of how a fast, automatic and sophisticated cognitive specialisation can develop in an appropriately scaffolded environment without depending on specific innate structure[7]. Niche construction provides an alternative explanation of folk psychology. We are all Polgars with respect to the chess game of social interaction.

The argument so far has not placed any weight on environmental change. Even if there is a universal and stable human nature that folk psychology tracks, folk psychology could be built through downstream niche construction rather than via its Baldwinisation. The converse is not true, and I doubt that there is a universal and stable human nature. Automated skills vary from culture to culture and individual to individual and these skills profoundly change an individual's cognitive profile. Consider the differences in quantitative reasoning competence between an agent who has mastered the number system with positional notation and one who has not. Likewise, patterns of emotion and the propensity to act on emotion varies importantly (see for example (Nisbett and Cohen 1996)). There is certainly some evidence that as folk psychological skills develop from the skeleton of belief and preference, cultural differences in folk psychological vocabulary become apparent ((Nichols and Stich 2003) pp 205-209). In short, changes to human environments have profound developmental consequences. To the extent that we think successful interpretation

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[7] "Specific" matters here. I think it very like that the notion of a cause itself is innate. And if naive physics is indeed an innate module, it may provide conceptual templates for the idea of a hidden cause (like that of a force or an inner essence) which can be exported to other domains.

depends on tracking <u>contingent</u> and <u>variable</u> aspects of the way others think, we should doubt that interpretive capacities depend on innate folk psychological principles.

V Epistemic Technology

Let me now turn to the phenomena I have previously somewhat neglected: the role of epistemic technology in mitigating the problem of information load. I shall begin by sketching some of the forms of epistemic technology. Most obviously, we alter our environment to ease memory burdens. We store information in the environment; we recode it, and we exploit our social organization through a division of intellectual labour. Our contemporary environment is full of purpose-built tools for easing burdens on memory. These include diaries, notebooks and other "organisers". Filofaxes are new tools, but purpose-built aids to memory are certainly ancient. Pictorial representation is over 30,000 years old. Furthermore, and deeper still in the past, ecological tools have informational side-effects. A fish-trap can be used as a template for making more fish-traps (Mithen 2000). Moreover, we re-code information in public language to make it easier to recall. In songs, stories and rhyme, the organization of the information enables some elements to prime others. Such re-coding enables us to partially substitute <u>recognition</u> for <u>recall</u>. The division of intellectual labour also reduces the memory burden on individuals; no-one has to master all the information a group as a whole needs.

We transform difficult cognitive problems into easier perceptual problems. We do this when we re-present quantitative information as a pictorial pattern, in pie-charts, graphs, maps. Likewise, we transform difficult perceptual problems into easier ones. For example, in shaping wood with a chisel and hammer, it is useful to mark the spot you intend to strike, making it easier to focus attention on the exact working surface.

We transform difficult learning problems into easier ones. For we alter the informational environment of the next generation. We do not just provide information verbally: learning is scaffolded in many other ways. Skills are demonstrated in a form suited for learning. Completed and partially completed artefacts are used as teaching

props. Practice is supervised and corrected. The decomposition of a skill into its components is made obvious; subtle elements will often be exaggerated, slowed down or repeated. Moreover, skills are often taught in an optimal sequence, so that one forms a platform for the next. Engineered learning environments play their most obvious role in intergenerational information flow, but these techniques also mediate horizontal flows of information.

We engineer workspaces so that frequent tasks can be completed more rapidly and reliably. For example, skilled bartenders use the distinctive shapes of glasses and their sequence to cue recall for customers' orders and to code the order in which they will be served. Their ability to respond accurately to multiple simultaneous orders plummets if they are forced to use identically shaped glasses (Clark forthcoming). Cognitive tools, too, are simplified and standardised to enhance performance on repeated tasks. Improvements in notation systems — the switch from imperial to decimal currency and measurement — makes many routine calculations easier, faster, and less error-prone.

Finally, as Dennett in particular argues, cognitive technology also has profound developmental effects. For example, in (Dennett 2000), he distinguishes between the capacity to have beliefs about beliefs and the capacity to think about thinking. On his view, even if non-human primates have beliefs about beliefs, they cannot think about thinking. Agents in a culture with enduring public symbols inherit an ability to make those symbols themselves objects of perception and to manipulate them voluntarily. Imagine a group of friends making a sketch map in the sand to co-ordinate a hike. Those representations are voluntary and planned. Dennett suggests that we first learn to think about thoughts by thinking about these public representations. In drafting and altering a sketch map, we are using cognitive skills that are already available. They are just being switched to a new target. Moreover, manipulating such a public representation makes fewer demands on memory; no-one has to remember where on the map the camp site is represented. Rich metarepresentational capacities are developmentally scaffolded by an initial stage in which public representations are objects of thought and action. While obviously very speculative, this idea seems very plausible to me.

In summary, epistemic technology — building tools for thinking, and altering the informational character of your environment — makes possible much that would otherwise be impossible. Moreover, for the most part, the effectiveness of epistemic technology is not linked to the pace of environmental change. Optimising your workspace; turning memory tasks into perceptual ones; using templates, public representational media and good notation systems all enhance your capacity to learn about your environment. And they do so independently of the pace at which that environment changes. But though epistemic technology plays a crucial role in explaining human intelligence, the use of epistemic technology is itself informationally demanding. I think Clark, in particular, tends to overlook this point. For he focuses too much on epistemic tools that are specifically tied to a single agent (Clark 2001; Clark 2002; Clark forthcoming). For example, in The Extended Mind, Andy Clark and David Chalmers develop a thought-experiment about an Alzheimers sufferer (Otto) who manages his problem by writing down in a notebook crucial information. They argue that the information in the book plays the same functional role for Otto that ordinary belief plays for other agents (Clark and Chambers 1998). That is not quite right. Otto's external memory is less reliable after dark; when he forgets his glasses; when his pen leaks or his pencil breaks; when it rains and his book gets wet. And we have not yet considered epistemic sabotage by other agents. To the extent that others have access to his notebook, Otto is at risk of thought insertion and deletion. These problems do not arise for such of Otto's information that he still codes internally.

Clark's favoured examples of the use of tools to extend our cognitive abilities tend to be of solitary activities: an academic writing a paper by revising drafts; cutting, pasting and annotating his way from one version to the next. Problem solving is not typically such a solitary vice. Think instead of conversations, discussions, brainstorming. Likewise, scientific labs are shared spaces, and the tools are often shared tools; notebooks, experiments, programs and papers are more often than not the result of many hands and minds. The same is true of decision and action in many commercial and administrative organisations. Files, for example, are often joint products. In short, epistemic technology is often used in a public and sometimes

contested space and this has important implications for the cognitive demands it imposes.

1. Jointly used epistemic artefacts are often less than optimal for any of their users: they need to be <u>individualised</u> at each use. Moreover, though human interactions are often co-operative, they are not exclusively so. The possibility of deception and the hidden agendas of others cannot be ignored. Files are sometimes doctored and their users have to be alert to this possibility. Agents using common tools cannot afford to be dumb.

2. Public representations have to be interpreted. Thus maps of an underground system typically represent the order of the stations and the connections between the various lines, but they do not map the distance between stops. Moreover, these features of maps and similar representations are variable and contingent, so they cannot simply be implicit in the automatic routines for the use of a representation.

3. Models and templates also require interpretation. A fish-trap carries information about how and where to make other fish-traps. But the template cannot be blindly copied, even by an agent who could commit every detail to memory. A fish-trap has to be modified for its individual location: for the specific tidal inlet it will block at low tide. That is often true of artefacts. When another agent makes an artefact for his own purposes, it is rarely ideal for me. The other agent may be larger or shorter; weaker or stronger; a left-hander. I shall need to modify as well as copy his production.

4. Symbol systems are now amongst our most important epistemic artefacts. Without positional notation and without algorithms which decompose large arithmetic operation into elementary ones, accurate quantitative reasoning would be impossible. Yet the appropriate use of these symbol structures is cognitively demanding. The innumerate are not rare in western societies, even though they make serious attempts to make numeracy skills universal. The arbitrary symbol systems of language impose greater demands still. Counter-deception is a problem whose informational load is both heavy and unpredictable: there is no telling in advance what you will need to

know in order expose another as a liar. This vetting problem is particularly pressing for linguistically coded information. The arbitrariness and stimulus-independence of linguistic symbols make language a powerful system. But they also make it a deception-subject system..

5. The use of epistemic tools in a public space involves quite complex problems of co-ordination. A recipe is a fairly standard example of an epistemic artefact. So consider a group of friends jointly producing a meal by following a recipe. Each agent must (a) monitor what others are doing; (b) negotiate a division of tasks; (c) negotiate a division of shared space and shared work surfaces; (d) negotiate a division of shared tools — who gets to use which chopper when. Successful co-ordination depends what the agents know of one another, their materials and their tools. We often solve such problems effortlessly, but that shows we are smart, not that the problems are easy.

Time to sum up this stage of the argument. In discussing epistemic technology, I have had four aims. The first was to highlight the variety and the potential power of epistemic technology. The second was to show the developmental consequences of epistemic engineering. The purely internal mechanisms of the mind become more powerful as a result of using epistemic tools (Dennett 1993; Dennett 1996; Dennett 2000). In these respects there is no difference between my views and those of Dennett and Clark. In addition, though, I have pointed out, third, that these techniques make few assumptions about the pace at which environments change. Even in a fast-changing world, they enhance the power of individual learning, and they enable solutions to be spread and improved horizontally. Finally, and very importantly, the use of epistemic technologies has evolutionary consequences. For tool use is itself a high-burden activity. The use of such technology is itself an aspect of the selective landscape that has transformed human cognitive capacities. Epistemic technology — storing information in the world, and improving the local epistemic environment — is not a way of making a dumb naked-brain smart by adding the right peripherals; it is not a way of making dumb brains part of smart systems. As with the other strategies, epistemic technology is not a complete solution in itself to the problem of cognitive load. The use of epistemic technology itself must be supported by some mix of quasi-modules and modules.

Let me end with a quick review of the argument. Contra the fast-and-frugal heuristics program, much human decision making has a high information load. Good decisions require access to, and use of, generous amounts of information. I have sketched three evolutionary responses to this problem. All are important, for response depends on the rate of environmental change, and different aspects of human environments change at very different rates. Even so, I have emphasised non-modular evolutionary responses to high information loads, in part because they have been less discussed, and in part because I doubt that many aspects of human environments are stable on evolutionary time-frames[8].

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