Evolutionary Approaches to Rational Choice

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Abstract

This chapter seeks to enrich and extend thinking about the Rational Choice perspective to offender decision-making and its pivotal application in Situational Crime Prevention, by taking an evolutionary approach, still uncommon in crime science and criminology. It begins by introducing basic concepts of evolution, covering the brain and behaviour, levels and types of explanation, the strained relationship with social science and the evidencing of evolutionary processes. The focus then shifts to rationality, covering decision-making itself; the wider suite of processes needed to understand rationality in action; and specific discussions of cooperation, humans' wider 'socio-cognitive niche', and development. While evolutionary issues are addressed throughout, the penultimate section covers how things have unfolded over evolutionary history; and the significant connection between maximisation of utility in contemporary rational choice, and maximisation/optimisation of fitness in evolution. The conclusion raises practical, empirical and theoretical questions for crime science.

Keywords: crime science, situational crime prevention, rational choice, evolution.

Dobzhansky (1973: title) stated that 'Nothing in biology makes sense except in the light of evolution.' It arranges apparently disjointed facts in natural history as a coherent body of knowledge explaining and predicting many facts about life. We should therefore consider how far the evolutionary perspective illuminates human rationality, including that of offenders.

As other chapters in this handbook elaborate, the Rational Choice perspective (RCP) is a lynchpin of crime science, and especially of situational crime prevention (SCP). It focuses on the here-and-now of criminal decision-making with its agenda of maximising reward and minimising risk and effort (e.g. Clarke 2013). Offender motivation is taken as given and detailed mental mechanisms of perception, motivation and choice are under-emphasised in pursuit of 'good enough theory' (Clarke 2013) centred on crime as opportunity. Intended for practitioners, this heuristic has been considered insufficient for leading-edge science

(Bouhana 2013; Ekblom and Hirschfield 2014). Moreover, richer understanding of *offenders* may be necessary to help refine *situational* interventions (Ekblom 2007) – for example, how, and why, adolescents handle risk differently from adults, should inform interventions targeted on this age group. One radical path to enrichment is to research the *evolutionary* connections of RCP. This not facilitates importing theories, findings and research methods from diverse disciplines into crime science, but also helps view the familiar from fresh angles.

Forays into evolution and biological ecology in crime science are rare. They include Cohen et al. (1995) on evolutionary expropriative strategies; Ekblom (1997, 1999, 2015) on arms races; Felson (2006) on crime and nature; Optimal Foraging Theory e.g. Bernasco (2009); and a guide by Roach and Pease (2013); see also Sagarin and Taylor (2008) for exploration of 'natural security' by biologists. As will be seen, evolution can unfold in domains beyond the biological. Hence *cultural* evolution, with cumulation and transmission through ideas or memes rather than genes (see e.g. Aunger 2000; Caldwell and Millen 2008) also pertains to the evolution of rationality. These processes interact, through gene-cultural coevolution or dual inheritance (Henrich and McElreath 2003).

This chapter proceeds as follows. Basic concepts of evolution are introduced, covering brain and behaviour, levels and types of explanation, the strained relationship with social science and the evidencing of evolutionary processes. Next the focus shifts to rationality, covering decision-making itself; the wider suite of capacities and processes needed to understand rationality in action; and specific discussions on cooperation, humans' wider 'socio-cognitive niche', and development. While evolutionary issues are addressed throughout, the penultimate section covers how things have unfolded over evolutionary history; and the significant connection between maximisation of utility in contemporary rational choice, and maximisation/optimisation of fitness in evolution. The conclusion raises practical, empirical and theoretical questions for crime science.

Some points to bear in mind when reading this chapter. First, although crime-related illustrations are emphasised, processes and capacities peculiar to crime are rare. This is unsurprising because evolution explains what is *common* to humans as one species compared to others, rather than focusing on *individual differences*. RCP and SCP particularly chime with this since they view offenders as essentially normal people with broadly normal motives/preferences and psychological makeup, acting in situations occasioning criminal opportunities. However, broader approaches like Situational Action Theory (Wikström 2014) cover differences in criminal propensity too; and it is the *capacity* to develop criminal propensity under certain conditions that may be universal. Second, the biological evolution of behavioural tendencies in this chapter is treated as equivalent to that of anatomy and physiology—obvious given that individual thought and action occur through neurological mechanisms. But learning and cultural evolution are also highly significant and are often brought in. Lastly, crossing disciplinary boundaries challenges terminology: references below to agents, organisms and creatures are equivalent.

1. What is evolution?

Biological evolution is a threefold process undergone by all organisms. Generation of *variation* in anatomy, physiology or behavioural tendency among individual members of a species is followed by natural or sexual *selection* in terms of differential probability of survival and reproduction in the species' habitat, which may challenge individuals with competition for resources or mates, conflict, and predation. Variants better adapted to their environment, or alternatively put, meeting appropriate fitness criteria, tend to survive and reproduce more than their conspecifics. Mechanisms of *inheritance*—predominantly through encoding of DNA in genes—transmit the properties of the variants to subsequent generations. All this produces a gradual increase in the proportion of variants in a given breeding population which possess features fitter for survival and reproduction. This mechanism operates over many generations, where the species as a whole, and in particular its genes, 'learn' what it takes to flourish in its normal habitat. Variety may be generated by recombination of gene variants via sexual reproduction, or through point mutations and other copying errors in DNA.

Of course, an organism's *genotype* is not the only influence on its *phenotype* (adult form). Individual genes interact with one another and with the environment in successively more complex ways as the organism develops from fertilised egg to maturity. Nature and nurture are inseparable (just as disposition and situation combine in generating contemporary behaviour). In humans particularly, much of the environment individuals must adapt to is social, i.e. comprising other people.

Fergusson et al. (2011) illustrate how genetic inheritance and early life experience interact. They show the probability of maltreated children developing violent and antisocial tendencies is mediated by the genetically-varying activity of monoamine oxidase A (MAOA) – an enzyme which breaks down dopamine. But the apparent violence-promoting effect of low-activity MAOA *only* appears if individuals experience maltreatment during childhood – hence this is a genetic effect contingent on proximal causes.

1.1 Evolution, the brain and behaviour

Since the human brain has evolved like the hand or eye, and since its neurological structure and operation underlie psychological processes, it is reasonable to suppose that psychological mechanisms and the behaviour they generate may partly derive from evolutionary experience, as transmitted by genes. As Cosmides and Tooby (1994) neatly put it,

> The applicability of evolutionary biology is based on a simple but powerful idea. Form follows function: the properties of an evolved mechanism reflect the structure of the task it evolved to solve. This approach has teeth because there is only one class of problems that evolution produces mechanisms for solving: *adaptive* problems. These are problems that recurred across many generations during a species' evolutionary history, and whose solution statistically promoted reproduction in ancestral environments. By identifying and modelling the adaptive problems humans faced during their evolution, researchers can make educated guesses about the designs of the complex computational devices the human brain embodies, and about many of the specific design features they required to be able to solve these problems. [329, original emphasis]

The approach known as *evolutionary psychology* (e.g. Tooby and Cosmides 1992) holds that natural selection has equipped humans with some specific evolved psychological mechanisms—a 'Swiss army knife' of modules—that conferred adaptive advantage in the past. Each supports specialised thinking about a particular kind of technical or social problem repeatedly confronting our Palaeolithic ancestors (which crime scientist would not warm to the problem-specific orientation?). Each applies a distinctive set of rules and representations, and is a kind of 'reasoning instinct'. To quote Tooby and Cosmides again,

> Although instincts are often thought of as the polar opposite of reasoning, a growing body of evidence indicates that humans have many reasoning, learning, and preference circuits that (i) are complexly specialized for solving the specific adaptive problems our hominid ancestors regularly encountered; (ii) reliably develop in all normal human beings; (iii) develop without any conscious effort: (iv) develop without any formal instruction; (v) are applied without any awareness of their underlying logic; and (vi) are distinct from more general abilities to process information or behave intelligently….They make certain kinds of inferences just as easy, effortless and 'natural' to make as spinning a web is to a spider or building a dam is to a beaver. [1994:330]

The hypothesised conditions under which our distinctively human mental adaptations arose are termed the 'Environment of Evolutionary Adaptedness' (EEA: Bowlby 1969, equivalent to the historically 'expected' habitat). They occurred mostly in the Pleistocene epoch (1.8m-11000bp). Then, modern humans and their predecessors lived in small hunter-gatherer tribes, all of whose members knew each other intimately; there was no permanent settlement, agriculture, private property, large interacting populations, or mass communication. The proposed problems that modules evolved to solve include habitat selection, foraging, competition from small armed groups, parental care, language acquisition, contagion avoidance, sexual rivalry and social exchange (Tooby and Cosmides 1992). Several of these are of obvious significance to crime scientists.

In combination with contemporary developmental and environmental factors, these modules influence how we interpret and behave in different situations. Tooby and Cosmides (1994; see also Pinker 1994) claim that massive modularity and its repertoire of specialist problem-solving methods is more powerfully adaptive for organisms than the rational decision making methods of logic, mathematics and probability theory. They further argue that the massive modularity approach eclipses the perspectives of *bounded rationality*—i.e. rationality modified by a series of limitations and biases (Simon 1955; Kahneman 2003), and of *heuristics*, an alternative and long-standing approach to understanding adaptive behaviour based on satisficing (Simon 1976; Kahneman et al. 1982). (Chapter X in this handbook covers both.)

From an evolutionary perspective neither boundedness of rationality nor heuristics are shortcomings from some absolute standard of perfect rationality. They are an optimisation solution, juggling brainpower (and the energy and material requirements to build and run powerful brains), time to decide and availability of information, against the overall contribution to survival and reproduction. For example, heuristics are simple, shallow but effective rules-of-thumb, which are effective most of the time in the EEA and occupy relatively little of the brain's limited processing capacity. Gigerenzer and Gaissmaier (2011) even demonstrate that under some circumstances ignoring part of the information relevant to decisions can lead to more accurate judgements. According to Schulz (2011) few economists consider decision-making speed and frugality alongside accuracy; however, the whole package is important for survival.

Proponents of these diverse perspectives battle on. Gintis (2009) holds that cognitive biases and irrationalities undermine the rational actor perspective underlying economic theory. Brighton and Gigerenzer (2014), advocates of heuristics, maintain that rational choice models only work in ‘small worlds’, where the dimensions of the problem to be decided are pre-given, but fail in ‘large worlds’, where the dimensions themselves have to be defined and clarified.

Mention should also be made of Ormerod’s (2012), agent-based modelling approach to games. He sees *imitation* as an efficient alternative adaptive process to rationality in complex environments where the pay-off to various strategies is constantly changing. This relates to the ‘costly information hypothesis’ (Henrich and McElreath 2003), which sees trade-offs in effort and advantage, between acquiring behaviourally useful information about the environment via individual learning, versus the social equivalent.

But the massive modularity approach to EP has itself been challenged from the opposite direction by Heyes (2012a) and colleagues, under a ‘new thinking’ label. Rather than merely addressing relatively recently-arisen differences between humans and hominid apes, this takes a longer historical perspective, reaching way before the Pleistocene, offering wider cross-species comparison. In strong contrast to what it calls ‘High Church Evolutionary Psychology’ (p2092) it suggests that rather than recently-emerged cognitive *modules*, humans are endowed with uniquely powerful, *domain-general* cognitive-developmental mechanisms. She offers the metaphor of the human hand in contrast to the Swiss army knife of modularity—the hand being of far longer and more gradual evolution, and being both highly functionally- and structurally-integrated and extremely adaptable. The ‘new thinking’ also highlights the importance of co-evolution and cultural evolution in generating gradual, incremental change.

This divergence of models has implications for crime science. For example, whether the ‘risk, effort, and reward’ dimensions of criminal choice are universal or differ between module domains; and whether and when the decisions of criminal involvement, commission or desistance can be viewed as small or large world-related: perhaps the latter applies to innovative crime. And whether we should attend more to *imitation* as an alternative to rational choice.

1.2 Levels and types of explanation

Different levels of explanation were used above; to avoid confusion we must distinguish between them. Suppose, say, that people are predisposed to prefer sweet foods. Tinbergen (1963) describes four ways of understanding this pattern of behavioural preference. *Functional* explanations consider here-and-now benefits to individuals of acquiring sweet foods, for survival and reproduction. In non-humans these are unconscious. In humans, often these may be processed as cognitively-mediated goals involving reflectivity and symbolic thought. (Nevertheless, until the scientific era all we knew was that we liked sweet foods, though not why.) *Mechanistic* explanations refer to contemporary underlying causes whether proximal (active in situations immediately preceding or hosting the behaviour, e.g.

a state of hunger or sight of chocolate) or more distal (e.g. the market price for sugar). (Note that goal-directed behaviour is ultimately reducible to causal mechanisms but these involve feedback loops homing in on the desired end-state. And note, too, that psychological mechanisms may in turn be redescribed in neurological/biochemical terms – e.g. glucose sensors in the hypothalamus.) *Developmental* explanations describe how individuals acquires the behavioural tendency whilst progressing from egg to adolescence to adult, and more generally through learning (as such they are an instance of distal). *Ultimate* causes cover evolutionary history, relating to the period when the behaviour first evolved, and the preference for sweet things emerged and conferred adaptive advantage on those individuals who possessed the genetic variants that underlay it. This historical account resembles the functional—but becomes significant when environmental conditions *change*, generating dysfunctional lags. Thus uninhibited pursuit of sweetness was an excellent adaptation in the EEA where such treats were rare and to be rapidly consumed at every opportunity, But in the abundant present, our scarcity-derived preferences jeopardise survival e.g. via obesity.

Because genetically-transmitted influences must act via the development of the phenotype in each successive generation, evolutionary approaches to cognition often adopt developmental perspectives. It is during development, and the extended juvenile learning period in higher animals, that environmental influences also exert themselves (whether as prolonged processes like deprivation or critical incidents like traumatic events): information about the here-and-now environment is incorporated in the organism's competences and acquired goals. In this respect higher cognitive development is less 'canalised' than, say, the basic development of vision, making room for cultural inputs, covered below.

1.3 Evolution and social science

Whichever of the rival EP perspectives prevails, we should refute the argument that EP sees significant human psychological/behavioural tendencies as mere 'wired-in' fixed action patterns. This has underlain much of the criticism from conventional social science, long resistant to evolutionary explanations (for a refutation see Roach and Pease 2013). The dominant assumption has been that the young mind is free of any content that does not originate in the senses and the social world, and is equipped only with a few content-independent rules of inference (Tooby and Cosmides 1994)). But from the EP perspective these assumptions are false. And each mechanism envisaged by EP is primed to detect and react to specific, distinct, environmental stimuli. As James and Goetze (2001) put it:

> Different environmental stimuli trigger different mechanisms, and we may have a large number of such mechanisms. If indeed this is the correct way to understand human psychology and associated behaviors, then any complete explanation will necessarily involve a discussion of environmental stimuli and activated mental mechanisms. [9–10]

Thus EP approaches are entirely compatible with *situational* approaches to crime. The *developmental* emphasis in the 'new thinking' approach additionally views the emergence of the general purpose cognitive capacity of humans as a product of protracted childhood interactions between genetic potential and environmental experience. Since most of humans' environment is social, this allows much scope for transmission, through social learning, of *cultural* influences, and indeed the evolution of culturally/linguisticallymediated layers of cognitive ability, including logic or moral reasoning. These ‘add-ons’ may underlie ‘everyday’ rational choice processes for most of us, although their culturally-advanced equivalents in economics or moral philosophy are rarely used by criminals!

This prompts consideration of wider Darwinian evolutionary processes than the biological/genetic model: while all follow the same ‘evolutionary algorithm’ (Dennett 1995), they are mediated by different mechanisms. Cultural evolution can be viewed as the variation, selection and replication of ‘memes’ (Dawkins 1976; Aunger et al. 2002). Analogous to genes, these are ideas, designs for tools and weapons, tunes, and complexes like religions or moral causes. Cultural replication itself works through several mechanisms operating on different scales: Godfrey-Smith (2012) distinguishes imitative selection from the population of intracultural variants of behaviour (i.e. individuals choosing what/who to copy); cumulative cultural adaptation (e.g. adjustments to climate change); and the most macro-level, ‘cultural phylogenetic change’ (for example, the Neolithic revolution shifting from hunting/gathering to farming).

‘Gene-culture coevolution’ or ‘dual-inheritance’ theories (Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981) envisage interactions between biological and cultural processes, the classic example being the evolution of dairying culture in Neolithic Northern Europe alongside genetic tolerance for lactose (milk sugar) previously indigestible by adults. Of more particular interest, Sterelny (2012) states the importance of *techno-social* coevolution in bestowing language on hominins (those species, ourselves and extinct relatives, that split from apes on the distinctively human line of descent) and turning them into cooperative foragers. He argues that improvements in technical (foraging) and social skills (gestural communication) were mediated by common cognitive processes controlling complex sequences of action. Pressure for improvement in technical competence enhanced social as well as technical skills, and vice versa, in a positive feedback loop.

Complex action sequences include scripts, a significant field in crime science (Cornish 1994), but script performance generally requires a string of decisions, some of which will have salient ‘rational choice’ aspects. Proficiency with weapons and tools, communication, collaboration and foraging have clear implications for emergence of competence at both committing, and defending against, crime-like behaviour. The last phrase is used because obviously the cultural, societal and institutional definition of *crime* as we know it did not exist in the hunter-gatherer bands in which humans emerged.

In sum, both cultural and developmental processes and the significance of situational triggers firmly link EP to contemporary social phenomena—if not always recognised by the academics who study them. As will be seen, biological and cultural evolutionary processes have supported the evolution of rationality, in the course of which they have imposed their imprints on it.

1.4 Establishing evidence for EP influences

Gould and Lewontin (1979) and others have attacked facile ‘evolutionary just-so stories’ (as in Kipling’s ‘how the elephant got its trunk’) in which evolutionary enthusiasts have uncritically posited adaptive functions and evolutionary histories behind a range of behavioural and anatomical features of particular organisms, including humans. In the present context we risk over-attributing aspects of rationality and other crime-related features to specific evolutionary circumstances and processes.

Gould's point is now broadly accepted. Evidence for EP influences must be triangulated from diverse sources—experimental, comparative, developmental, archaeological, genetic, physiological and so forth. More specifically, Heyes (2003), drawing on Pinker (1997) and others, describes how a candidate for cognitive evolution is assumed to be phylogenetic (i.e. evolved and inherited) if there is evidence a) of 'poverty of the stimulus', i.e. that the adaptive properties of the cognitive process could not have arisen through experience alone, because that experience supplied too little information to account for the complexity of the process; or b) the adaptive properties are genetically heritable. Conversely, it is classed as ontogenetic (arising developmentally) if the evidence suggests 'wealth of the stimulus', i.e. that the adaptive properties could be products of experience; and if there is no evidence of genetic heritability. 'Research relevant to the poverty or wealth of the stimulus compares the development of cognitive processes across species, cultures, and subgroups within a population. Wealth is indicated by correlated variation in experience and development, whereas poverty is implied by invariant development in the face of experiential diversity.' [715]

Nonetheless, the evidentiary issue remains unsettled. Shultz (2011) warns that evidentially, simple heuristic models (à la Gigerenzer) suffer from an ongoing lack of crucial information about our past, a shortcoming he generalises to all evolutionary approaches to rationality.

Subtler approaches to evidence and analysis are required. For example, Heyes (2003), discussing adaptive specialization of cognitive processes, distinguishes between *constructive* and *inflectional* processes. The first refers to qualitatively different cognitive mechanisms; the second to same mechanisms but processing different input, e.g. from the perceptual system and ultimately from the outside environment. The evidence trail for these distinctions is complex and painstaking, no just-so stories here.

2. Rationality

Rationality relates to organisms, their mental processes and behaviour (and perhaps their tools – Ekblom in press). It is variously a process of generating rational behaviour; a capacity and/or a state of mind for so doing ('s/he is not entirely rational'); or a description of a particular item of thought or behaviour ('that act was irrational'). Rationality is addressed elsewhere in this handbook; here the interest lies in the process and capacity, its function and its evolutionary history.

Rationality is addressed through diverse disciplines: Kacelnik (2006; see also Houston et al. 2007) distinguishes *PP-rationality* (psychology and philosophy, centring on mental mechanisms/processes rather than outcomes); *E-rationality* (economics, centring on behavioural outcomes/choices leading to utility maximisation); and *B-rationality* (biology, centring on evolutionary/ecological aspects of organisms' adaptation to their habitat). Attempts have been made to explore the relationship between these in considering whether biological insights can support or illuminate economic thinking on rationality (e.g. Cosmides and Tooby 1994; Schulz 2011), or vice-versa (e.g. Okasha and Binmore 2014). RCP in crime science has elements of both E-rationality (risk, effort, reward) and PP-rationality (boundedness, hot and cool decisions—van Gelder et al. 2014), but has barely touched on B-rationality.

Psychological (PP-) studies of the mediation of rationality have come to distinguish between diverse mechanisms—experiential versus analytic (Slovic et al. 2004); and the related 'system 1 versus system 2 thinking' (Kahneman 2011). (These are further discussed in the chapter on dual process theories.) System 1 is fast, automatic, frequent, emotional, stereotypic, subconscious; system 2 slow, effortful, infrequent, logical, calculating, and conscious. Extremes of System 1 may connect, for example, to Katz' (1988) account of the emotional and phenomenological processes of, say, righteous, enraged murder.

By contrast to PP-rationality, 'E-rationality', used in economics, is predominantly instrumental, the goal being the *maximisation of expected utility*. This can be used to predict patterns of behaviour without paying much attention to underlying mechanisms. However, to class someone as rational we must assume, or seek evidence for, the goals the person is pursuing and how they relate to one another in terms of priority, transitivity etc. The divergence of focus between psychological process (PP) and economic outcomes/goals (E) relates to the dual 'caused agent' perspective (Ekblom 2010): the offender as *caused* by environmental and/or internal mechanisms (perceptions of risk, states of intoxication or arousal etc.) but simultaneously *causing*, i.e. actively constructing and executing plans and goals.

The third discourse, 'B-rationality' (for biology), is mainly a subsidiary of E-rationality where outcomes relate to costs and benefits in an ecological context. We revisit this below.

2.1 Decision-making

The discussion of rationality usually centres on the process of decision-making, often involving issues of risk/uncertainty. We find choices straightforward to talk about both scientifically and in the vernacular. But we must first ask what exactly decisions are, and how they fit within an evolutionary framework; and second (below), consider the wider 'rationality suite' of processes and systems within which they act, develop and have evolved with.

Decisions are taken at various stages of cognition. We are continually making *perceptual* decisions—'is it a police car or an ambulance siren?' The outcome of perceptual decisions may inform more general *action* decisions. Prey species have evolved to cope with knife-edge balancing of feeding versus fleeing in deciding whether lions, say, are hunting or just ambling past. Here, the action choices are predetermined, and merely await input from the perceptual decision regarding which is activated. Less critical situations allow time for weighing up action choices in terms of risk, effort and reward.

With action decisions, the mechanisms are diverse. We have already noted the system 1/ system 2 duality. A partially-related phenomenon addressed by van Gelder et al. (2013) is the distinction between decision-making undertaken in 'hot' versus 'cool' states of mood or emotion. However, even the most calculating and cool of decisions appears to rely on *affect* or 'gut feeling' to swing the choice one way or another, affect being described by Slovic et al. (2004) as a 'faint whisper of emotion'. [312] Strong evidence for this comes from people with particular brain-damage who, whilst perfectly articulating the pros and cons, cannot make decisions. This led Damasio (e.g. Bechara et al. 2000), to contend that rationality is a product both of the analytical and the experiential mind; and more particularly to develop the 'somatic marker' theory in which all thoughts (perceptual and symbolic images) become marked with positive or negative affect, whether through experience, evolutionary pre-programming (think snakes) or some combination. One evolved function of emotions—affect especially—thus seems to be *integral* to decision-making rather than an *alternative,* even with 'instrumental' behaviour, where visceral emotional processes are absent (cf. Van Gelder et al. 2013).

At the functional level, why take decisions at all? The answer must relate an organism's evolved needs for survival and reproduction, to its contemporary mechanisms for delivering those outcomes in relation to ecological factors in its habitat. Decision-making is pervasive—bacteria decide whether to secrete an enzyme to exploit a particular foodstuff when that becomes available; plants decide when to drop leaves in relation to drought. With humans, foraging for food, tackling an opponent or burgling a house, the decisions are just more numerous, interlinked and subtle.

Fundamentally, decisions are needed because organisms have multiple goals to juggle. Their priority and urgency may shift dynamically over various timescales (e.g. the state of their energy reserves (Houston 2014)); and as a function of immediate or anticipated environmental conditions which may make demands, supply resources or place constraints on the organism. These goals, and the behaviours that serve them, may well be in conflict or competition. This threatens paralysis or vacillation if some capacity is not available to routinely detect or anticipate such circumstances and force a choice to resolve the affair.

The decision-making capacity of contemporary organisms has diverse origins. A core capacity has evolved *genetically*—any organism incapable of making ecologically-relevant decisions is unlikely to survive and replicate. But additional decision-making capacity built on the genetic inheritance is acquired *developmentally*. This may partly be sourced from individual learning undertaken during a single lifetime, partly (in humans) from social learning/instruction. The last may draw on cultural knowledge which has itself evolved over multiple generations, including the invention of formal logic and economic theory.

Cultural inputs also supply *motivational, emotional and reputational influences* in valuing decisiveness and strong planning and execution; but occasionally the opposite, in subcultures of 'anti-rationality' as documented by Wright and Decker 1994. More generally, the psychological 'handles' on which emotions tug have evolutionary origins. Fearless animals or those which don't like their food are likely to die sooner, and individual members of group-living species who are unconcerned with status are less likely to breed.

The *time* dimension of rationality is important. Decision-making generally addresses the future, anticipating that particular harmful or beneficial events may happen, necessitating prior action. The capacity to anticipate, and the content of assumptions and predictions made, will usually derive from the past. Biological evolution itself resembles a learning process (cf. Hammerstein and Stevens 2012) where the genes defining a particular species have learned about stable features of their habitat, e.g. climate or terrain, and over generations the resulting phenotype is appropriately adapted.

Only ecological variations which are stable over many generations can be addressed by genetic learning, leading in higher organisms to the evolution of ‘instincts’. Variations too rapid for genes to track can however be picked up by cultural evolution, and the fastest by individual within-lifetime processes of learning. Plotkin (1997) makes an interesting point that rationality of any kind can only evolve if there is ‘predictable unpredictability’—i.e. variation of the food supply, say, or the population of predators, within a normal range. Total chaos makes anticipatory decisions impossible; total certainty makes rationality superfluous to survival. ‘Learning and memory mechanisms, or some further capacity for rationality, are the way in which the problem of the uncertain physical future is solved.’ [149] The intimate connection between risk and decision-making is noteworthy.

2.2 The wider rationality suite

The decision-making capacity has not evolved in isolation. It is embedded in a wider suite of tendencies, capacities and processes which together enable agents to cope and flourish in their habitat. A fuller understanding of the current function and working of decisions and rationality, their development from birth and their evolutionary history must embrace these internal and external contexts in which decisions are made and acted on. Crime science focuses on problem-solving approaches to prevention; but problem-solving by offenders is equally relevant (Ekblom in press).

Rational choice can only function if the chooser has an array of *preferences* or goals. Criticisms of RCP in criminology have sometimes mistakenly equated these preferences exclusively with material ones (money, goods etc) whereas immaterial rewards like status are also relevant. In fact, rationality is about *relations* between goals/preferences and the behaviour for realising them; it makes no presumptions about which preferences the chooser has. Economists term such factors *exogenous*. Many of these preferences are claimed to derive from our evolutionary history, as with the sweetness example above.

The options brought to the offender’s attention for decision may be shaped by *perceptual* factors involving the assessment of uncertain possibilities, costs, threats and risks (e.g. Slovic et al. 2004). According to Wikström’s Situational Action Theory (2014) certain criminal options simply *do not occur* to many people. But morality is not always automated. *Moral reasoning* may impose constraints and skew choices. Johnson (2014) argues that we have evolved to be moral creatures in order to survive and flourish in groups: ethical reasoning is a form of problem-solving primarily concerned with situations where our values and interests conflict with those of others. Any social species encounters such situations, so morality is not uniquely human, though our own morality is more complicated, subtle and reflective compared with that of other animals. In particular we have evolved, culturally and genetically, what Johnson calls a capacity for *imaginative moral deliberation*, a simulation of alternative courses of action and their ethical consequences.

Broader reasoning/inference processes underlie both system 1 and system 2 decisions although the latter takes more explicit and complex routes (Heyes 2003). Indeed Van Gelder et al. (2013) prefer the phrase ‘reasoned choice’ over ‘rational choice’. The evolution of human linguistic/symbolic capacity is another component in supporting sophisticated, and communicable, reasoning.

The rationality process must operate on *knowledge*. The basis of choice must be knowledge of both generic and specific operating environments/habitats, knowledge in the form of a behavioural repertoire and the pros and cons of alternatives; self-knowledge of one's own capacity for tackling an adversary of particular strength.

Heylighen (1991) combines evolution and cybernetics to enrich understanding of the ecological function of decisions. As adaptive systems, organisms often face a situation whereby maintenance or achievement of a particular goal state is jeopardised or 'perturbed' by some circumstance. They must therefore choose items from their action repertoire which are most likely to compensate that particular perturbation. Knowledge of both *actions* and *environment* enables them to choose the former from the variety of alternatives at their disposal that are most likely to fit the latter, in taking (or returning) them to their desired goal state. According to Heylighen, knowledge *substitutes* for real encounters with the environment: thus, following a perspective presented by Campbell (1974), knowledge serves as a 'vicarious selector'. It represents, and allows anticipation of, the selective action of the environment, whether a lion lurking on the path home or police monitoring a drug den. *Natural* selection is in effect internalised; Popper (1972) has a related view of anticipated action, namely 'ideas dying in our stead', which we will revisit. The more varied and complex the environment that agents must control, the greater the variety of responses they need at their disposal, an expression of Ashby's (1957) Law of Requisite Variety. Thus the more sophisticated the decision-making capacity must become, along with the *planning and design* capacities to generate the variety of responses and fit them to purpose.

The salience of *opportunity* in RCP and SCP makes it important to connect it to the rationality concept. The default understanding of opportunity is as a property of the environment. But deeper reflection suggests that, like the larger-scale ecological concept of the niche (P and J Brantingham 1991) it is a conjoint property of several things. These are, tthe particular goals of the offender; the properties of the environment; the knowledge and wider psychological capacity of the offender to perceive the opportunity (affordance) in that environment; and the material resources and psychological capacity of the offender (Ekblom and Tilley 2000) to cope with the hazards and exploit the vulnerabilities the environment contains. Implicit or explicit reasoning processes may connect possible coping and exploitative actions to the offender's goals. What becomes an opportunity thus depends on the evolving resources of the agent to perceive and exploit it; and changes over time of the environmental components, including, again, other people and organisations. With criminal arms races (Ekblom 1997, 1999, 2015; Sagarin and Taylor 2008) these coevolve.

Typically many individual crimes are viewed as impulsive, gain-now-pay-later affairs. Making decisions through system 2 often involves exercise of some kind of self-control or *executive function* to actively impose longer time-frames and consideration of broader issues, including moral ones, on the estimation of costs and benefits. What happens *after* decisions is also important: it is pointless carefully making a rational, utility-maximising choice with delayed gratification if one cannot then stick to that choice over the appropriate time period. Ambitious, organised crimes in particular may require considerable self-control and patience in execution, and complex crime scripts involving a cascade of linked decisions as the script is adapted on-the-fly to current environmental contingencies. Whether such capacities are used for good or bad purposes, Jablonka et al. (2012) see their origins in the requirement to develop strong inhibitory control to serve both the finicky, patience-demanding requirements of tool-making, and those of 'alloparenting', where individuals besides the actual parents look after children (think of the patience of kindergarten teachers).

Pre-decisional neutralisation in anticipation of guilt feelings, and post-decisional rationalisation are also relevant here, presumably psychologically/culturally uniquely human. Whether these offer any *adaptive* advantage is debatable: they may serve respectively to make decisions easer and to maintain them once made. More generally, neutralisation and rationalisation are examples of 'metacognition', the processes by which we monitor and influence our own thinking and that of others (for a review see Frith (2012)), with clear adaptive value especially in group living.

More strategic decisions on criminal involvement, continuance and desistance may last decades (although some of the lock-in may derive from the sustained response of the environment to the choice made, e.g. persistent relationships with criminal associates, or wider criminal reputation). Their mediating mechanisms may differ from those underwriting criminal tactical choices.

2.3.Rationality and cooperation

Research (e.g. Novak 2011) has emphasised the cooperative, altruistic nature of humans, unusual in the animal world. Schneier (2012) takes this up in the security field, noting that we should study cooperation in both the wider society, and within groups of criminals.

More specifically, Gold (2014) reviews theories of 'team reasoning', a perspective developed to account for apparently non-rational choices of players in game theory experiments. Gold proposes that players come to identify with their team and make choices that maximise team rather than individual benefit. Gold connects the switching between individual- and team-mindedness with the controversial issue within evolutionary science of multilevel selection (especially, selection not just between individuals, but between groups). But for crime science, immediate implications surely centre on whether studying rational choice among cooperating co-offenders or offending organisations might benefit from a distinct team reasoning perspective.

2.4 Rationality and the wider human socio-cognitive niche

Cooperation is part of a wider picture that informs what our rationality deals with today and how it evolved. Whiten and Erdal (2012) ask how a moderately-sized ape, lacking the formidable anatomical adaptations of professional hunters like lions, could compete over the same prey. The conventional answer (e.g. Tooby and DeVore 1987) revolves around the elaboration of a new cognitive niche based on intelligence and technology (for example the advanced inferential reasoning in tracking prey—how many, whether wounded, how long ago they passed; and the refinement of weapons for the kill). This enables humans to mount what Tooby and DeVore refer to as ‘evolutionary surprise attacks’ which escalate the arms race such that prey cannot keep up through their own biologically-evolving counter-adaptations, slower to emerge and more limited in scope.

Whiten and Erdal argue, however, that cognition alone is insufficient. They present evidence that a fuller answer ‘lies in the evolution of a new socio-cognitive niche, the principal components of which include forms of cooperation, egalitarianism, mindreading (also known as ‘theory of mind’), language and cultural transmission, that go far beyond the most comparable phenomena in other primates. This cognitive and behavioural complex allows a human hunter-gatherer band to function as a unique and highly competitive predatory organism.’ [2119] Whiten (2006) termed the complex ‘deep social mind’ to emphasise the core features of mental interpenetration and adjustment of individual to group-level goals (as with ‘team reasoning’ above). The consequent fitness benefits, and positive feedback between the individual elem,ents may explain the tripling of human brain size in the last 2.5 million years.

One might add that much of this boost was less for dealing with other prey or predator species, but our fellow humans. Indeed, such foraging and predatory capacity used by individuals or groups against other humans and their assets, is what makes human criminals potentially so resourceful and adaptive (Ekblom and Tilley 2000; Ekblom 2007; Cohen et al. 1995), and capable of running those arms races against one another. Another relevant EP factor is human concern with reputation (e.g. Wilson and Daly 1985; Schneier 2012), which may have either criminocclusive or criminogenic consequences depending on whether the reputation is judged by wider society or fellow gang-members.

2.5 Rationality and development

Breland and Breland’s (1961) famously-entitled article ‘*The Misbehavior of Organisms*’ describes numerous examples of different species’ readiness to learn particular associations or actions, but resistance to others. Humans are more versatile but conventional EP suggests we will most easily learn what our inherited mental modules have prepared us for. For example, we should be better at learning how to spot cheats than to do some more abstract logical equivalent (Tooby and Cosmides 1992).

The process of development from birth to adulthood offers, as said, a distinct level of explanation for the decision-making and rational capacities of individuals traversing each stage. Personal and social learning of individually and culturally-acquired knowledge play significant roles in such development—but what of biological evolution? The discipline known as ‘evo-devo’ (e.g. Carroll 2005) studies how evolutionary changes are realised through their effects on developmental pathways. It has long been obvious that individuals’ rational capacity increases from childhood through maturity. More recently, findings on adolescence, and its associated changes in neuro-anatomy, perception of and appetite for risk, have reached an interesting stage (e.g. Steinberg 2005; Slovic et al. 2004; Roach and Pease 2013 on evolution and the age-crime curve; and see chapter on criminal decision-making of juveniles in this handbook). Current research strongly suggests that adolescents undergo a phase when:

> changes in arousal and motivation brought on by pubertal maturation precede the development of regulatory competence in a manner that creates a disjunction between the adolescent's affective experience and his or her ability to regulate arousal and motivation. To the extent that the changes in arousal and motivation precede the development of regulatory competence—a reasonable speculation, but one that has yet to be confirmed—the developments of early adolescence may well create a situation in which one is starting an engine without yet having a skilled driver behind the wheel. (Steinberg 2005: 70)

The big question as far as 'ultimate' explanations from evolutionary history go is whether this disjunction is currently or previously *adaptive*, or just an accidental outcome of other pressures with no, or negative, benefit for survival or reproduction. Risk-taking has been postulated to serve various adaptive functions despite its potentially high cost, with risky behaviours (including crime-related ones) largely driving elevated adolescent mortality rates across diverse species (see Spear (2010)). Set against these costs, these adaptive functions have been claimed to include increasing the probability of reproductive success among human and other species' males (Steinberg & Belsky, 1996). In humans this is hypothesised to stem from social status mechanisms originating in sexual selection (Wilson and Daly, 1985—the 'young male syndrome'). Steinberg (2005) notes that evidence in animal and human studies supports a link between increasing levels of reproductive hormones and sensitivity to social status, a fact consistent with the link between puberty and risk-taking. These fit an evolutionary pattern.

Whether adaptive or otherwise, this shifting relationship between emotion, risk perception/ appetite and behavioural control means that what may be effective situational influences on offenders during adolescence may differ from those which work during adulthood. Similar risk-related considerations could apply with *gender* differences but this dimension has so far awakened little interest in SCP.

3. The relationship between evolution and rationality

This section discusses two issues central to the relationship between evolution and rationality: the elaboration of rationality throughout evolutionary history; and the ahistorical relationship between maximising utility and maximising evolutionary fitness.

3.1 Evolutionary history

Biological evolution builds on prior art, extending here, simplifying there, finding a new adaptive function for anatomical or behavioural features originating in some other context (our upright walking stance, say, may derive from tree-climbing). The result is a succession of modifications which weave a very crooked ascent to some peak in the 'fitness landscape'. Biological evolution is blind, and every new step must convey immediate adaptive advantage to the generation inaugurating it. Therefore, that peak may not be the theoretically highest one in the totality of fitness space. Biological evolution may be trapped at a local peak because once there, all alterations take the species downhill in fitness terms before it can ascend a higher peak. Evolutionary processes as much involve conserving what works as finding something better (some vital enzymes have remained essentially unchanged over millions of years and those transplanted from humans into yeasts may still function). This contributes to 'evolutionary lag'.

Slovic et al. (2004) give an example how the ‘affect heuristic’ (i.e. managing risks through gut feelings alone) hits the fitness limits. ‘It works beautifully when our experience enables us to anticipate accurately how we will like the consequences of our decisions. It fails miserably when the consequences turn out to be much different in character than we anticipated.’ [321] They identify two ways that experiential/system 1 thinking misguides us. One results from the deliberate manipulation of our affective reactions by those who wish to control our behaviours (as in advertising and con-tricks); the other from the existence of stimuli in our environment that are simply not amenable to valid affective representation. ‘If it was always optimal to follow our affective and experiential instincts, there would have been no need for the rational/analytic system of thinking to have evolved and become so prominent in human affairs.’ [319]

Only human learning and cultural evolution are capable of looking, and leaping, across the deep valley that may separate a local fitness maximum from a far higher distant peak. Dennett’s (1995) ‘Tower of Generate and Test’ conveys a key evolutionary sequence spanning the range from biological to individual and cultural learning. This is an imaginary tower where each floor has creatures able to find better and smarter moves, and find them more quickly and efficiently.

1. Darwinian creatures, on the ground floor, rely only on *genetically inherited* knowledge, and die when this fails to predict or avoid trouble in their environment. The faulty knowledge is thus filtered out.
2. Skinnerians on the next floor are less likely to die but with simple trial-and-error learning ‘kill off’ *behaviour* that doesn’t work, and preserve that which does.
3. Popperian creatures on the next floor can *imagine* outcomes in their heads and solve problems by thought. In Popper’s words (1972:244), this ability ‘permits our hypotheses to die in our stead’. Evolutionary pressure is not halted, but taken off-line from the real world into protective environments, and re-cast in acts ranging from intuitive imagination to research and development. This is how we can leap across to higher peaks.
4. Gregorian creatures, named after psychologist Richard Gregory who noted (1981) that *cultural artifacts* not only require intelligence to produce them, but also then enhance their owner’s intelligence. Such artifacts can include tangible things like scissors or calculators; but as Dennett (1995) notes, they also include ‘mind tools’ including verbal/symbolically-mediated logic and rationality. With these, Gregorian creatures can find good moves and evolve new behaviours much faster.
5. Scientific creatures rigorously, collectively and publically *test hypotheses and undertake ‘rational’ design* based on understanding of causal mechanisms.

The creatures in this sequence are successively more intelligent and efficiently innovative, and the process and scope of decision-making expands at each floor. In fact, this is a case of the ‘evolution of evolvability’ (e.g. Dawkins 2003), in which certain adaptations boost adaptive potential. Ekblom and Pease (2014) and Ekblom (in press) discuss this concept further regarding adaptive criminals, citing Gregorian socio-technological examples such as 3D printers and ‘script kiddies’ (software kits enabling amateurs to generate effective computer viruses). Related ‘bootstrapping’ concepts feature in Henrich and McElreath’s (2003) notion of the ‘evolution of cultural evolution’.

‘Better’ decisions, covering more issues, in more detail and perhaps over longer timescales, may only confer adaptive advantage if a species is committed to an intelligence-based strategy. (Some are not: sea squirts begin as mobile larvae but on maturity settle on rocks and promptly digest their now-redundant brain. And recall earlier discussion of the advantages of frugality and speed.)

Pressure to ascend the tower may come from competition, conflict or the struggle for survival in a rapidly changing environment, as arguably happened due to cycles of drought and damp in East Africa’s Rift Valley over the last few million years of human evolution (Maslin and Shultz 2013). Such changes effectively reshape the fitness landscape, removing the peaks organisms had climbed, and substituting others elsewhere. Continual change (evolutionary ‘disturbed ground’) makes for adapt*able* generalists like ourselves rather than highly adapt*ed* specialised species which die out when their EEA disappears. Humans are creating the same perpetually disturbed circumstances for favouring opportunist species like rats—and maybe opportunist fellow humans including criminals through disruptive technologies, business models and social media.

The cybernetician Heylighen (1991) considers the evolving requirements of mental control systems, where what these seek to control is some combination of the agent’s environment, and their own behaviour in that environment. As the level of complexity of a mental control system, and the variety of responses it can generate, exceed a threshold, the agent encounters problems, as with the Slovic et al. example. Heylighen therefore posits the need for higher levels of control to arise, via a ‘metasystem transition’, with the emergence of a new system controlling-the-controls of the level below. He argues that the emergence of higher control leads to an increase of response variety, while the increase of variety, if it is large enough, stimulates the emergence of a yet a higher control, in a positive feedback cycle.

Our own, uniquely human, rational level of control relies on symbolic concepts abstracted from their perceptual origins (e.g. ‘essence of cat’ as opposed to the whole vision of claws, dead birds, litter-trays etc). This provides generative creativity, producing a huge variety of action possibilities to choose between, a fact exploited by offenders (Cropley et al. 2010); and for practical purposes, free will. Heylighen also muses about the emergence of a new level at the present time: our ability to design and use collective rational models. (These range from the deliberate design of new antibiotics, to climate change models… to certain frameworks in crime prevention, e.g. Ekblom 2011). Whether and how *offenders* might come to use such models in their decision-making is debatable but sophisticated cyber-crime and fraud are where to look.

As Heylighen describes it the emergence and imposition of new, higher, control systems seems rather neat and bloodless; but the process, and the resultant composite systems, can be messy. The systems 1 and 2 model introduced earlier, and the ‘tower of generate and test’ above, illustrate the ‘layering’ often encountered particularly in biological evolution, where old and new layers function alongside one another. In humans the layers may conflict, as with impulsive versus reflective decisions, and/or emotionally hot versus cool ones (van Gelder et al. 2013). Cultural layers and influences add to the fray.

Slovic et al. (2004) hold that effective rational decision-making requires good integration of these modes of thought. Perhaps human mental conflicts over decisions are inevitably, perpetually messy, or are currently acute simply because the evolutionarily new cognitive layers have had insufficient time to 'shake down' into full coordination with the earlier layers. Apart from guiding our understanding of situational precipitators (Wortley 2008) and decision-swayers, such conflicts between layers originating at different periods in evolutionary history constitute a rich source of literature ranging from fiction to moral philosophy and the Freudian entities of Id, Ego and Superego. The diverse array of interactions between immediate situations, wider circumstances (e.g. prolonged stress) and humans' capacity to switch psychological states in terms of affect, moods, emotions and visceral feelings (e.g. sexual arousal or rage) has powerful effects on our rationality, well-documented in Van Gelder et al. (2013).

Biological evolution of complex organisms is slow, and changes from the EEA can leave them lagging behind, as seen. With humans, the lag is continually stretched by environmental changes from our own accelerating techno-social evolution. This now places us in situations lacking natural environmental inhibitors for behaviours like road rage and internet trolling (empathic stimuli from face-to-face interaction are missing). The ongoing cultural evolution of our own rationality dooms humans to experience perpetual perturbation in our conflicting control systems at both individual and collective levels, unless and until Heylighen's metasystem transitions provide temporary relief.

But the evolutionary literature is not yet settled. According to Dayan (2012) the clash of different decision-making mechanisms may not be just an evolutionary lag, but a *beneficial* adaptation. He views this struggle as providing valuable redundancy against errors in computing and maladaptive properties of the individual models on which the computations are based. Such internal competition thus may help to maintain robust decision-making. Of course, such robustness may be especially helpful in our self-complicated circumstances.

The scope for both cultural perturbations, and adaptations to them, may be wider than some evolutionary biologists imagine. The controversy between massive-modularity protagonists (e.g. Tooby and Cosmides) and those supporting general cognitive capacity was noted earlier. Heyes (2012b) especially questions the widespread assumption that it is biological evolution that produced and maintains the core cognitive processes enabling cultural inheritance. Using evidence from comparative psychology, developmental psychology and cognitive neuroscience, she argues that the development of imitation and other processes of social learning is remarkably similar to the development of literacy, and that the cognitive processes enabling cultural inheritance are *themselves* significantly culturally inherited rather than exclusively and directly genetic. This instance of 'evolutionary bootstrapping' can perhaps be likened to a switch from hardware evolution to software evolution.

Whatever the case, crime scientists should be cautious in assuming the universality and fixity of rational thinking across cultures and across situations. Brighton and Gigerenzer (2012) suggest there is no such thing as 'one true rationality', since rationality principles are *invented*, not discovered. The implications for RCP of this idea are that we must reconsider whether the simple table of 'risk, effort and reward' etc at the heart of, say, the 25 techniques of SCP (ref) remains entirely good enough (as Tilley 2014 argues), or should be decomposed into columns for specific *kinds* of risks, effort and rewards.

3.2 Maximising utility, maximising fitness?

Many writers (e.g. Becker 1976; Okasha 2011; Sterelny 2014) highlight the apparent similarity between maximisation of utility, central to RCP especially within economics, and maximisation/optimisation of evolutionary fitness in biology. Cosmides and Tooby (1994) talk of evolution creating the mental equipment whereby individuals' economic choices create the market: one invisible hand creating the other. Gintis (2014) argues that the 'rational actor' model integrates seamlessly with evolutionary biology, discounting on evolutionary grounds the received psychological view that human cognitive biases *undermine* the applicability of RCP. Indeed, Nettle (2012) argues that an evolutionary approach via error management theory predicts the sorts of contexts where biased decision-making might be anticipated: those with important implications for evolutionary fitness. The link, if valid, promises dividends in transfer of ideas, research methods and practice between these disciplines. But there are complications.

Both utility and fitness maximisation concern an organism's success in dealing with its environment, and both are claimed to play similar theoretical roles in their respective disciplines (Schulz 2014). In RCP, agents are assumed to make choices that maximise their utility, while in evolutionary theory, natural selection 'chooses' between alternative phenotypes, or genes, in line with fitness maximisation. consequently, evolved organisms often exhibit behavioural choices apparently designed to maximise their fitness, which suggests that rational choice principles might be applied to study non-humans (Okasha and Binmore 2014).

Crime science may gain from traffic in the opposite direction, for example in importation of thinking from the ecologically-based Optimal Foraging Theory (OFT). This was initially used in behavioural ecology to explain how animals search, choose, and process food; and extended to deal with how they handle predators, competitors etc. The conceptual heart of OFT as with RCP, concerns goal-oriented behaviour, with contemporary goals derived ultimately through natural selection acting over evolutionary history. Optimising foraging strategies involves making (rational) choices in terms of the budgeting of resources including time and energy, which maximise reproductive success hence evolutionary fitness. In other words, the *capacity* to forage optimally can be seen as a fitness-enhancing outcome of evolution; exercising that capacity in the everyday *conduct* of optimal foraging should enhance survival and reproductive success. Unfortunately, few OFT studies go on to show that decision-making leads to different fitness outcomes; one exception is Altman (1998).

The OFT-RCP link is explored in detail by Bernasco (2009) who has utilised OFT to derive hypotheses on offence specialisation, the use of time and space by property offenders, and the influence of police presence on offender behaviour. The fruitfulness of this approach leads him to conclude that, while OFT in itself adds relatively little that is not already in RCP, the importation of perspectives and methods from behavioural ecology that the link enables, enriches the approach to research and helps complete the wider picture of causal factors that the abstract RCP does not specify. More generally Gintis (2014) holds that a complete theory of behavioural choice must go beyond the rational actor model to incorporate ideas from both evolutionary biology and social psychology.

But the OFT/RCP linkage and the more general utility/fitness equivalence specific are not straightforward. Bernasco identifies differences between OFT as applied to humans versus animals. *Legal* behaviours almost always remain an alternative human choice and criminal involvement is usually embedded in a lifestyle mostly comprising legal behaviour; a distinction irrelevant to other animals. Animal choices are generally closer to life-or-death issues like obtaining the next meal whilst avoiding becoming one; whereas with humans, committing a (foraging-relevant) crime is a matter of less intense and immediately consequential choice—except, say, with drug dependency. However, Bernasco's latter distinction may diminish in significance if foraging is held to include choice-switching between immediate survival necessities versus the pursuit of reproductive opportunities. (Here are echoes of Maslow's hierarchy of needs e.g. see Tay and Diener 2011).) The animal will not die if it misses out on the latter (though it may feel frustrated), but seeking and courting a mate may jeopardise its personal survival (the extreme case being certain spiders where copulating males become 'wedding breakfast' for their partners).

But more general questions remain. Houston et al. (2007) say we cannot expect natural selection, lacking foresight, to shape organisms to act rationally in all circumstances, but only in those circumstances they encounter in their natural setting. Therefore fitness-maximizing behaviour might not appear when animals are placed in novel contexts. For animals, this may be in laboratory experiments; for humans, our own techno-social change is continually subjecting us to novelty.

Okasha and Binmore (2014: introduction) ask *when* it is possible to identify the economists' notion of utility with the biologists' notion of fitness; a question that needs addressing e.g. in relation to the import of OFT to crime science. Sterelny (2012b) maintains that their coincidence depends on whether information is transmitted vertically (between generations) or horizontally (between peers), and on whether or not group selection is a prevalent factor. From another angle Schulz (2014) identifies two processes affecting the equivalence of fitness and utility. 'Niche construction' is where organisms modify their *environment* to fit their needs; 'adaptive preferences' covers animals changing their desires to make *them* fit what is available. The former is the subject of active debate in fundamental evolutionary thought (e.g. Laland et al. 2009). It relates to criminal activity for example in *corruption*, where offenders subvert crime preventers; the latter is less clear but speculating, may have some link to sex offending, criminal involvement or displacement choices.

4. Conclusions—implications for crime science

This chapter has only touched the surface of the evolution/rationality field, one which remains moreover in considerable ferment. Hopefully it will encourage and assist crime scientists to undertake their own explorations. The field is uniquely challenging because of its recursive nature—thus for example we have the evolution of rationality as a fitness-optimising *process*, ultimately generating *products* in the form of brains which themselves support rational, utility-maximising decision *processes* which in turn feed back to biological evolution via improved prospects of survival and reproduction. The brains themselves adapt to more rapid changes in the social and physical environment through individual lifetime development and learning, and cumulative cultural change and transmission. The mechanisms and preparedness for learning have significant components from biological evolution but in turn support a 'bootstrapping' process where tools for learning, instruction and decision-making evolve culturally. At both biological and cultural levels there is evidence for evolution of evolvability itself; and biological and cultural coevolution has been shown to occur where each drives the other. But all this makes human evolution so exciting to study!

The evolutionary perspective on rationality raises numerous issues for crime science. The research evidence is currently too limited to supply firm answers, and we cannot know how far those eventual answers will be tweaks on contemporary research and practice or something more disruptive. But we can at least suggest questions to answer by our own research and by 'watching this space' in evolutionary studies:

- What are the particular *triggers* in the social and/or physical environment that might precipitate criminal behaviour, and once the criminal is ready to offend, how might they affect criminal decision-making? How might this differ for hot versus cool decision-processes?

- How are risk, effort and reward preferences *primed*—what is risky, what effortful and what rewarding as a function of evolutionary history as opposed to other more recent influences? How flexible is that priming during development and maturity?

- How has the very *capacity* for assessing risk, effort and reward, and for integrating these through decisions, evolved in, say, foraging behaviour? Has evolutionary history left its imprint on these? Does it make a difference whether inherited massive modularity, heuristics or general-purpose rationality underlie decision-making?

- How far can we continue to treat the risk, effort and reward columns of the 25 Techniques of SCP as *universals* rigidly applicable across all crime situations, or differing contextually by their triggering stimuli and/or their perception/estimation processes as these have evolved biologically, culturally or through learning?

- Should we be investigating *team reasoning* in co-offending and organised crime?

- Should we consider *imitation* as an alternative/complementary source for criminal behaviour to rational choice?

- What factors influence the *development and the shape of rationality* in individuals, especially but not exclusively during adolescence? Are any of these sensitivity factors evolutionarily-informed? Do they relate differently to strategic versus tactical criminal decisions?

- Does (criminal) rationality differ between *small- and large-world decisions*, and do the latter inform studies of criminal innovation?

- Are there wider evolutionary influences we should consider on the performance of the *executive control system*? What implications do these have for crimes usually committed under low self-control versus high self-control?

- Should we look further into whether the concepts of *niche construction* and its mirror image *adaptive preference* can be applied to crime science, e.g. on corruption, our understanding of opportunity and (non)displacement?

Once we start answering these questions we can apply them to crime prevention—testing them through practice. This contributes to Campbell's (1974) evolutionary epistemology.

But… we should heed the evidentiary warnings on over-attribution to EP, and to outdated retention of adaptations to the EEA. We should keep abreast of rapid changes in evolutionary science, paying special attention to thinking on the fitness/utility relationship. We should not expect answers to be simple and unconditional. We should not consider rationality in isolation but in its wider social/ecological/technical context, the context to which our brains and our cultures have adapted. We should consider in parallel, biological and cultural evolution, and individual learning and development.

Hopefully this chapter has demonstrated two distinct benefits for crime science from linking rationality with evolution: extending and refining the specific content of our theoretical, empirical and practical address to crime and its prevention; and seeing the entire field from an entirely fresh perspective. Let's keep our ideas evolving—generating variety but also being selective!

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