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Reply

Connecting behavioural biologists and psychologists: Clarifying distinctions and suggestions for further work

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Abstract

This article is a reply to the commentaries on our target article, which relates our group's work on simple heuristics to biological research on rules of thumb. Several commentators contrasted both these approaches with behaviour analysis, in which the patterns of behaviour investigated in the laboratory are claimed to be near-universal attributes, rather than specific to particular appropriate environments. We question this universality. For instance, learning phenomena such Pavlovian or operant conditioning have mostly been studied only in a few generalist species that learn easily; in many natural situations the environment hinders learning as an adaptive strategy. Other supposedly general phenomena such as impulsiveness and matching are outcome models, which several different models of simple cognitive processes might explain. We clarify some confusions about optimisation, optima and optimality modelling. Lastly, we say a little more about how heuristics might be selected, learnt and tuned to suit the current environment.

Keywords: Animal cognition; Ecological rationality; Impulsiveness; Optimality modelling; Rule of thumb; Simple heuristic

We find lots in the commentaries that will stimulate further research and help establish common ground between our Centre for Adaptive Behaviour and Cognition (ABC) and animal research. For instance, we appreciate Kyonka and Church's ideas about how heuristics like Take The Best could be tested on animals using operant techniques. Another instance is how Shettleworth uses existing results from animal psychology to encourage us in a broadening of perspective from rules of cue usage to rules of cue learning. Rather than pick out isolated points with which we take issue, we will concentrate on themes that were the concern of several commentaries.

1. Universal versus situation-specific mechanisms

ABC has emphasised that because a heuristic's performance depends on the environment, we expect different heuristics to be used in environments with different statistical structures. Heuristics are thus general only in the sense that the same heuristics might be used in a variety of domains with common statistical structures and by a variety of species. Three commentaries

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(Mazur, Williams, Shettleworth) contrast this with the much more general mechanisms that behaviour analysis has emphasised. Mazur makes claims of universality for certain mechanisms of learning, whereas Williams does admit of limited situation-specific exceptions such as bird song.

If these were indeed universal constraints about how brains work, there would be no problem with heuristics being designed around them; cognitive constraints exist whether or not any are universal. However, we would claim that Mazur and Williams underestimate the exceptions. For instance, not all stimuli-response associations are equally readily learnt, sometimes in ways that make adaptive sense: Shettleworth mentions Garcia and Koelling's (1966) work on which cues to toxicity rats can learn. Claims of universality may actually be based on rather few species, and, as Williams mentions, it may be a deliberately biased sample of generalist species that can learn how to use Skinner boxes.

The data are also biased in that learning is inevitably studied in situations where it is easy to learn. In many natural situations individual learning, such as Pavlovian or operant conditioning, is difficult because events are rare, single errors are dangerous, lifetimes are short, or because it is difficult to get immediate feedback about the consequences of a choice. Also complex situations, as Mazur mentions involving "multiple cues and multiple dimensions, and multiple source of uncertainty", make the interpretation of feedback much more difficult than in the simpler well-controlled world of a Skinner box. In some situations, the past may even be an unreliable guide to the future (for instance, with a non-renewing evenly distributed resource, finding an item should be the stimulus *not* to look there again). In all these situations, individual learning need not be as ecologically rational as alternatives, such as a hardwired response (see Cross and Jackson's discussion of "Darwinian" animals) or, especially in humans, a reliance on social heuristics such as doing what the majority of your peers do (Laland, 2001). Thus, whereas Pitts envisages that triage doctors might learn valid cues via a history of differential reinforcement, research actually finds that opportunities for feedback are rare and that doctors instead mostly apply rules taught in medical school (Gigerenzer, 2002). We would therefore claim that the supposedly universal mechanisms of individual learning are applicable only in particular types of environments, although perhaps these are widespread ones. It may help to connect ABC's work with behaviour analysis by considering that each concentrates on a different region along a continuum between mechanisms that are more and less widely applicable. One lesson of such a perspective for students of learning is that they should establish in what environments individual learning is ecologically rational compared, say, with a hardwired response.

2. Outcome versus process models

Amongst the other supposedly universal laws mentioned by Williams and Mazur, impulsiveness and matching contrast with heuristics in another way: they are descriptions of the behaviour (outcome models or as-if models) rather than models of the cognitive processes that generate the behaviour. Sanabria and Killeen briefly make this distinction and our viewpoint is also consistent with Pitts' doubts that matching is itself an evolved heuristic but rather results from an interaction between a particular evolved susceptibility to stimuli and the environment.

As an illustration, Thuijsman et al. (1995) have provided two examples of simple heuristics that would enable a bee to monitor the rewards available from two species of flower and prefer the one producing more nectar. One heuristic is the "ε-Sampling Strategy": stick with a single species except with some low probability ε sample the other species and then switch if the payoff exceeds an average of recent payoffs. The other even simpler heuristic is the "Failures Strategy" in which a bee switches species whenever it has experienced n empty flowers in a row. When a bee is studied in isolation both heuristics (and many other learning rules) can produce matching behaviour. Incidentally, although matching in this one-bee environment is not adaptive, the underlying rules are adaptive in that, in a natural environment in which bees are competing with many others, both rules generate an ideal-free distribution in which no bee could do better.

It would be interesting to consider what sorts of simple heuristics might produce impulsiveness and, more specifically, roughly hyperbolic delay-of-reinforcement gradients. Hyperbolic gradients are contrasted with the "rational" expectation of exponential decay (Read, 2004). Impulsiveness research studies the