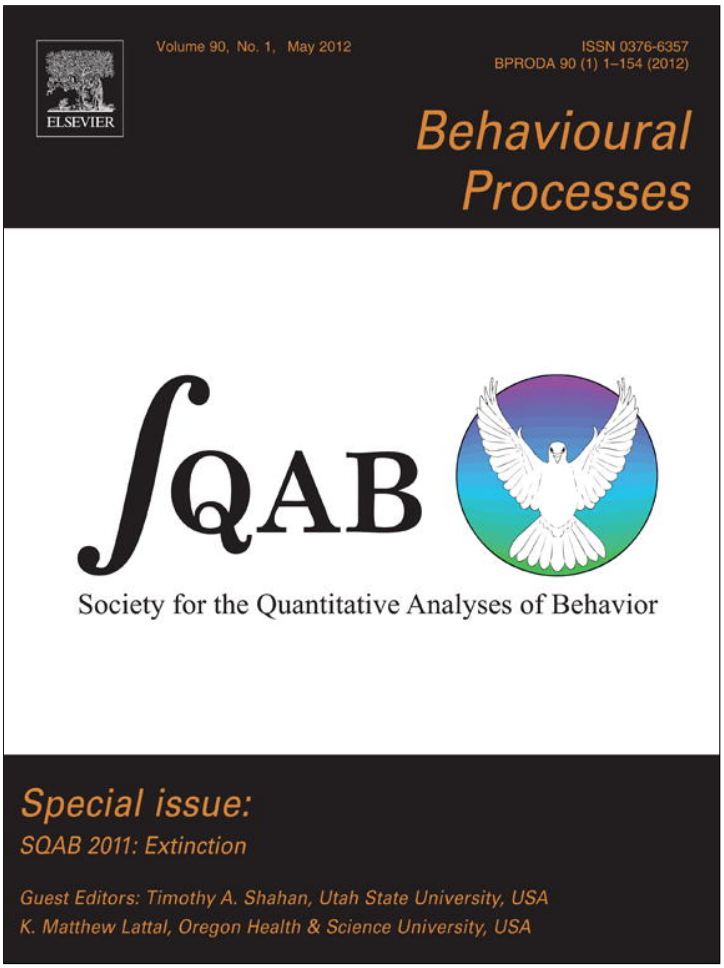

Behavioural Processes 90 (2012) 87–88

Contents lists available at SciVerse ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

On rationalism and optimality: Responses to the Miller and Nevin Commentaries

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ARTICLE INFO

Article history:
Received 25 February 2012
Accepted 27 February 2012

Keywords:
Rationalism
Optimality
Information theory
Contingency
Cue competition
Assignment of credit

ABSTRACT

Modern materialist rationalism is the doctrine that principles governing behaviorally important aspects of the world have become implicit in the structure of purpose-specific information-processing mechanisms through evolution by natural selection. These principles are mostly, but not entirely mathematical. Because the evolutionary process tends to optimize, the computations performed by these mechanisms tend to approximate the optimal computation. This doctrine does not imply that animals always make rational and/or optimal choices.

1. Response to R. Miller Commentary

Rationalism is not the doctrine that animals always do what is rational. Nor is it the doctrine that animals "evaluate propositions. . .and make evolutionarily optimal decisions." It is the doctrine that the mechanisms by which the brains of animals process information have built into them implicit commitments to enduring properties of the world. The enduring truths important to at least this rationalist are mostly, but not entirely, mathematical. For example, when neural tissue integrates a velocity signal with respect to time to generate a position signal with respect to time, it makes an implicit commitment to the analytic truth that position is the integral of velocity. Mathematical truths have always been true and always will be. One does not need to speculate about the conditions that prevailed eons ago.

The rationalist does not believe that animals or humans always do what is evolutionarily optimal, that is, rationalists do not believe that "normal subjects would [never] display a dysfunctional behavior." The counter examples to such a claim are legion. The modern rationalist believes that the brain contains mechanisms that were shaped by evolution to solve particular problems, just as were the sense organs. I confess that I find this assumption so plausible that I am bewildered by the fierce empiricist opposition to it.

If the assumption that the brain contains problem-specific computational mechanisms is true, then it is important to identify the problems that have brain mechanisms dedicated to their solution, in the same sense that lungs are dedicated to solving the gas-exchange problem. And, it is important to consider the nature of the computation that a mechanism with that function might perform. In considering this, the rationalist believes that one should ask what the optimal computational solution is and what it predicts. The assumption underlying this heuristic is that if a problem is important enough to have a mechanism devoted to its solution, there will have been an evolutionary pressure to optimize it.

Here is an example of how this way of thinking applies to the phenomenon of extinction: Animals inhabit a stochastic, non-stationary world. On some occasions, Event B follows Event A; on others, it fails to follow. A parameter of this stochastic process is the probability of Event B given Event A. The world is non-stationary, because the value of this stochastic parameter itself changes:during some periods, A predicts B with high probability; during others, it predicts it with low or even zero probability. The rationalist conjectures that estimating stochastic parameters and recognizing changes in them has been important to animals for as long as there have been animals. The rationalist believes that animals that do a better job of dealing with risk will on average have more grandchildren than animals that do a poorer job of it. Therefore, the rationalist believes that: (1) There may be a computational mechanism in the brain whose function is to detect changes in stochastic parameters. (2) If there is, it has probably been under optimizing selection pressure since the Precambrian. (3) Therefore, that mechanism may be a good approximation to the optimal mechanism. Believing this, the rationalist asks, Would an optimal change-detecting mechanism exhibit the partial reinforcement extinction effect? That is, would the number of trials to detect a decrease to 0 probability be inversely proportional to the

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doi:10.1016/j.beproc.2012.02.015

pre-change probability (because that is an experimentally established quantitative fact about the partial reinforcement extinction effect)? It turns out that the answer is, yes, as I show in my paper.

It is an interesting question whether the same result can be derived from models that do not assume a change-detecting mechanism and, *a fortiori*, not one that has been optimized. Associative theories of learning are such models, and there are a great many of them. The question then is, Is there an associative model of the learning process that predicts that trials to extinction should be inversely proportional to the prechange probability of reinforcement? To my knowledge, there is not. I have looked through Schmajuk's (2010) volume without finding a model that claims this result. I would have thought that the authors of a model that did give this result would call attention to this virtue, because explaining this result has been recognized for decades as a major challenge to theories of learning.

2. Response to J. Nevin Commentary

In suggesting that the information-theoretic measure be used to measure contingency in conditioning paradigms, I am not suggesting a quantitative law of behavior, nor describing a feedback function. I am inclined to think that operant theorizing has overemphasized the behavioral importance of response-reinforcement contingencies. Be that as it may, to address the question empirically, we need a measure of contingency. If we cannot measure contingency, how can we bring experimental results to bear on the question of whether and to what extent and under what conditions behavior-reinforcement contingencies are psychologically important? To my knowledge, there has not previously been a generally applicable measure of contingency. One reason psychologists interested in learning should know information theory is that it offers a generally applicable measure of contingency. This is true whether or not animal brains make information-theoretic computations.

It is true that several others have called attention to the importance of *relative* delay in conditioning (Staddon, 1972; Jenkins et al., 1984; Kaplan, 1984; Fantino et al., 1993), as have my collaborators, John Gibbon and Peter Balsam. So, why, one may ask, come at this empirically well-established fact from an information-theoretic perspective? The advantage of the information-theoretic perspective is that it unifies our understanding of the role of temporal parameters in conditioning protocols with our understanding of cue competition (Balsam and Gallistel, 2009; Balsam et al., 2010), which is known to reinforcement-learning theorists as the credit assignment problem. These have always been regarded as quite unrelated problems.

The information-theoretic perspective grounds the principles of our psychological models in mathematical principles that govern the world with which our brains must cope. For a rationalist, this is highly desirable. In the Rescorla–Wagner model, the limit on net associative strength is just a psychological postulate. It is neither motivated by a fact about the world, nor by a fact about associations. Likewise for the postulate that associative strengths add. Why should associations have these properties? Is there anything about the nature of associations that implies that they should combine additively and that there should be a limit on their sum? If associative bonds are synaptic conductances, as many believe, then it is astonishing that they should add, because synaptic conductances do not combine, let alone combine additively. (Postsynaptic potentials *may* combine additively, though that is doubtful, but the conductances certainly do not.). From an information-theoretic perspective, it is an objective analytic fact that entropies add and that the source entropy limits the available information, the total information that all cues combined can convey about the timing of a reinforcement. The rationalist is inclined to think, "Ah yes, that is why the mechanism that solves the cue competition problem might be expected to have the properties assumed for the associative bond by the Rescorla–Wagner theory." The rationalist sees this as another example of the core rationalist doctrine that (largely mathematical) principles governing phenomena in the world have, over evolutionary time, become implicit in the structure of problem-specific brain mechanisms that have evolved to construct behaviorally useful representations of the world.

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