REVISITING THE FOUNDATIONAL AXIOMS OF GAME THEORY

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ABSTRACT

Since game theory came into being in 1944 with Von Neumann's publication of 'The Theory of Games and Economic Behaviour', it has been applied to a dazzling array of disciplines with varying degrees of success but it is worth noting its abysmal failure in its original domains of application: international relations and the field of economics. The reasons for this failure are two-fold. First, game-theoretic analyses of human relations rest upon flawed assumptions of a psychological nature that aren't constrained by psychological evidence. Second, any axiomatisation of human behaviour would need to summarise advanced knowledge of embodied cognition(i.e. complex quantitative relationships between psychology and physiology) that resists the axiomatisation process. For these reasons, the author recommends that scalable approaches to experimental psychology(rather than game theory) be used to inform domestic policy not least because internal threats are often underestimated.

1 Introduction

Since game theory came into being in 1944 with Von Neumann's publication of 'The Theory of Games and Economic Behaviour', it has been applied to a large range of disciplines ranging from economic theory to evolutionary biology and even cancer treatment [1]. In particular, it has strongly influenced the development of mathematical economics and countless applied mathematicians that develop theories of rational behaviour. On one level, game theory may be considered a triumph of the axiomatic approach to the development of the mathematical sciences, of which Von Neumann was a strong proponent. However, it is worth noting its abysmal failure in its original domains of application: international relations and the field of economics. Perhaps its biggest failure was Von Neumann's usage of game theory to justify a pre-emptive nuclear strike on the Soviet Union [5].

The reasons for this failure are two-fold. First, game-theoretic analyses of human relations rest upon flawed assumptions of a psychological nature that aren't constrained by psychological evidence. Second, any axiomatisation of human behaviour would need to summarise advanced knowledge of embodied cognition(i.e. complex quantitative relationships between psychology and physiology) that resists the axiomatisation process.

Having exposed the cognitive blindspots of game theorists, I propose advances in experimental psychology as a way forward.

2 The empirical validity of the axioms of game theory

Game theory is a normative theory of human decision making where humans are considered rational if they satisfy its axioms. The theory describes rational beings as agents whose preferences may be modelled by utility functions that satisfy the Von Neumann axioms [3]:

Completeness: An individual has well-defined preferences. Either they prefer A over B, B over A, or the perceived values of A and B are equivalent.

Transitivity: If an individual prefers A over B and B over C, then they prefer A over C.

and there are two more axioms of continuity and independence. But, the first two axioms are already sufficiently problematic.

Empirically, individuals rarely satisfy the completeness axiom. On some days, we may prefer apples over bananas. On others, bananas over apples. Second, most humans have an order of preferences that contains contradictions so transitivity is not satisfied either. It is possible to construct many sophisticated theorems and design 'efficient' markets with these axioms but they assume the most significant part of what remains to be proved.

The tacit assumption in these axioms is that humans are logically consistent information processing devices. However, this assumption is contradicted by empirical evidence on a daily basis. It follows that humans are irrational according to the theory and therefore the theory is not applicable to real humans.

On the other hand, if the value systems of individuals and communities may be approximated by utility functions, it is natural to ask how these functions behave and how they evolve over time. These are scientific questions, which concern the real world, are necessarily constrained by experimental and empirical evidence of human behaviour.

3 Experimental psychology as a way forward

3.1 Embodied cognition, or physiological constraints on human psychology

In the previous section, I raised doubts concerning the implicit assumption that humans are information-processing devices. Research in experimental psychology and robotics actually indicate that there are important physiological constraints on human psychology [6].

In fact, much of human intelligence is derived from human dexterity which has allowed us to build a large number of tools. If we had the bodies of jellyfish or dolphins our ability to interact with the physical world would be considerably diminished, and technology as we know it would not have developed. Furthermore, the central importance of motor control to the development of human psychology may be illustrated by noting that motor control in humans is almost entirely regulated by the cerebellum. This brain region which represents 10% of brain mass, contains 80% of the functional neurons.

Other important quantitative relationships have been established such as the relation between heart-rate variability and cognitive flexibility [7]. I mention cognitive flexibility because this faculty appears to be central to the human ability to simultaneously consider several contradictory ideas without the brain exploding.

In a world as complex as ours, I suspect that cognitive flexibility and not the completeness axiom, to be an important human feature.

3.2 Reinforcement learning and sport psychology

Ever since Pavlov performed his experiments on reinforcement learning, the field has made important advances in our understanding of human and animal psychology. One fundamental reason for this is that reinforcement learning theories, unlike game theory, are constrained by experimental feedback loops by definition.

The reinforcement learning framework is both effective and simple. At a time t, an organism in an environment E makes a decision a_t, obtains a reward r_t in consequence, and adapts its behaviour accordingly in order to maximise expected future reward. Then the objective of reinforcement learning researchers(a psychologist or neuroscientist) is to study such behaviour. Perhaps it is not surprising that the most important advances in Artificial Intelligence in the last decade came from reinforcement learning.

However, within the disciplines of human psychology most branches have so far ignored direct correspondences between physiology and psychology with the exception of sport psychology. In fact, sport psychology is particularly well-suited for reinforcement learning analyses. Not only does human physiology(ex. sensorimotor control) have a non-trivial role to play, but outcomes are always quantifiable(win/loss) and feedback loops are a key part of the training process.

One particularly nice feature of sport psychology is that it is scalable in the sense that the majority of humans have been introduced to sport, and it is a natural part of human evolution.