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Of matchers and maximizers: How competition shapes choice under risk and uncertainty

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ABSTRACT

In a world of limited resources, scarcity and rivalry are central challenges for decision makers—animals foraging for food, corporations seeking maximal profits, and athletes training to win, all strive against others competing for the same goals. In this article, we establish the role of competitive pressures for the facilitation of optimal decision making in simple sequential binary choice tasks. In two experiments, competition was introduced with a computerized opponent whose choice behavior reinforced one of two strategies: If the opponent probabilistically imitated participant choices, probability *matching* was optimal; if the opponent was indifferent, probability *maximizing* was optimal. We observed accurate asymptotic strategy use in both conditions irrespective of the provision of outcome probabilities, suggesting that participants were sensitive to the differences in opponent behavior. An analysis of reinforcement learning models established that computational conceptualizations of opponent behavior are critical to account for the observed divergence in strategy adoption. Our results provide a novel appraisal of probability matching and show how this individually 'irrational' choice phenomenon can be socially adaptive under competition.

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1. Introduction

Competition is a pervasive characteristic of the world—plants compete for light, water and pollination; animals are in continual competition for food, territory and procreation; and humans constantly compete in sports, for social status and companionship. The presence of social competitors in virtually all aspects of real-life decision making demands the development of socially adaptive choice strategies in a broad range of contexts. In this article, we examine how competitive pressures shape the adequacy of decisions made in simple binary choice probability learning paradigms (cf. Estes, 1964) that to our knowledge have only been employed with individual decision makers in social isolation. This research closes an important conceptual gap in the human probability learning literature by offering a socially adaptive account for a long-standing individual choice phenomenon known as *probability matching*.

Probability matching describes an inferior strategy of sampling choice options in proportion to the options' relative outcome probabilities in sequential probability learning tasks. The standard procedure in such choice tasks involves asking individual decision makers to choose repeatedly between two alternatives that reward the same payoff with unequal odds (e.g., with $p = .70$ and $1 - p = .30$). Assuming these outcome probabilities are stationary, payoffs are maximized by exclusively selecting the option with the higher reward likelihood—i.e., by *probability maximizing*—once the probabilities have been learned. By contrast, matching choices to outcome frequencies by choosing the more likely option on 70% of occasions and its alternative on the remaining 30%, results in markedly inferior choice accuracies and payoffs. Yet, probability matching is commonly adopted by individual decision makers (for a review see Vulkan, 2000). Context-independent interpretations of rational choice therefore consider probability matching as an erroneous choice anomaly and attribute its adoption to cognitive constraints of the decision maker. Within the framework of dual cognitive process theories, for instance, probability matching is assumed to represent a simple cognitive shortcut carried out by an intuitive cognitive system, whereas probability maximizing would arise if deliberation corrected this initial impulse (Koehler & James, 2009, 2014; Kogler & Kühberger, 2007; West & Stanovich, 2003).

What seems irrational in individualized context-free environments, however, can be optimal in ecologically plausible situations. Accordingly, an alternative view on probability matching holds that this tendency may emerge as a result of over-generalizing typically highly adaptive behaviors, for example, responding to limited and uncertain information about the true random nature of a choice task (Green, Benson, Kersten, & Schrater, 2010), searching for patterns when none exist (Gaissmaier & Schooler, 2008; Peterson & Ulehla, 1965; Wolford, Newman, Miller, & Wig, 2004), or when prospective competitive interactions are taken into account (Gallistel, 1990; Gigerenzer, 2000).

1.1. Probability matching in competitive environments

When decision makers seek to exploit limited resources under *natural circumstances* (e.g., forage for food or make money), they are rarely alone but typically in fierce competition for the exploitation of these resources with other agents. The more individual agents then choose the seemingly richest resource, the less each individual's gain. In nature, this situation cannot remain stable because agents who sometimes select options with potentially scarce resources that are exploitable under less competition would attain a key evolutionary advantage (Gallistel, 1990).

This argument is in line with the predictions of optimal foraging theory (MacArthur & Pianka, 1966), which assumes that animals behave in such a way as to maximize their evolutionary fitness. Within this concept, the model of the ideal free distribution predicts that a group of foragers will distribute their choices among resources relative to the options' reward potential—i.e., probability match—to optimize foraging success (see Fretwell, 1972). This group behavior creates an equilibrated evolutionary stable situation that does not give rise to conditions selecting against it. The predictions of the ideal free distribution have been approximated in various animal studies. Observations of foraging ducks (Harper, 1982), fish (Godin & Keenleyside, 1984), and ants (Lamb & Ollason, 1993) revealed proportionately matched distributions of these animal groups to resource allocations across patches.