



Rivals in the dark: How competition influences search in decisions under uncertainty

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ABSTRACT

In choices between uncertain options, information search can increase the chances of distinguishing good from bad options. However, many choices are made in the presence of other choosers who may seize the better option while one is still engaged in search. How long do (and should) people search before choosing between uncertain options in the presence of such competition? To address this question, we introduce a new experimental paradigm called the competitive sampling game. We use both simulation and empirical data to compare search and choice between competitive and solitary environments. Simulation results show that minimal search is adaptive when one expects competitors to choose quickly or is uncertain about how long competitors will search. Descriptively, we observe that competition drastically reduces information search prior to choice.

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1. Introduction

Whether the question is what to eat, where to live, or with whom to mate, decisions are often made under competitive conditions. This holds for species ranging from humans to hermit crabs. Arguably choosier than humans are about their housing, hermit crabs are always on the look-out for new and better shells. Because the abdomen of a hermit crab is extremely vulnerable, hermit crabs need find suitable seashells to protect their vital organs in order to pass their genes on to the next generation. When a solitary crab encounters an empty shell, it thoroughly inspects the potential new home. The crab will meticulously explore the outer surface of the shell looking for holes and weak points. It will then insert its vulnerable

abdomen into the shell opening to see whether the potential new home is a good fit. If the shell passes this thorough inspection, the crab may decide to discard its current shell and exchange it for the new one. However, when a *group* of crabs simultaneously encounters an empty shell, each individual crabs' search process is dramatically truncated. In this competitive situation, the crab nearest to the shell will make a split-second decision on whether or not to take it based on a brief visual inspection alone (Rotjan, Chabot, & Lewis, 2010).

Swap the hermit crab for a human and the shell for a television on a clearance rack, and intuition suggests that human behavior may be similar to that of hermit crabs'. On a slow shopping day, the leisurely shopper can take his time deciding whether or not to buy the television. He can thoroughly examine the television's attributes, look up expert reviews on his smartphone, or take advantage of the wisdom of crowds by soliciting advice from friends on a social networking site. However, on a frantic shopping day like Black Friday, the same shopper is likely to behave very differently. Surrounded by dozens of other eager

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shoppers, he might spend only a few moments looking at the television before deciding to grab it before someone else does. Why might competition reduce pre-decisional search so dramatically? What costs and benefits do organisms reap by reducing their search efforts in the presence of competition? What factors in choice options and the social environment affect good search rules? In this paper, we seek to provide initial answers to these questions using a new experimental paradigm that we call the *competitive sampling game*.

Organisms rarely have complete and certain information about options before making even the most consequential choices; instead, they must make choices in the darkness of uncertainty. To shed light on the available options, they must learn about those options' possible outcomes and their associated probabilities through an exploratory search process (Real, 1991). Most people go on dates before proposing marriage, vacationers research and compare hotels before deciding where to stay, and hermit crabs inspect new shells before making a move. After a period of exploration, organisms *exploit* an option by making a long-term consequential choice. Exploration and exploitation represent two diametric goals associated with choice, namely, gathering information about options (exploration) versus consuming an option (exploitation) based on current information (Cohen, McClure, & Yu, 2007). Although exploration provides organisms with more information, it can come at costs in the form of money, time, or lost opportunities. There is thus a tradeoff between exploration and exploitation: If you search too little, you might struggle to distinguish good from bad options. If you search too much, you may suffer from excessive search costs.

In solitary choice situations, the exploration–exploitation tradeoff has been extensively studied both theoretically (Brezzi & Lai, 2002; Gittins, 1979; Gittins, 1989) and empirically (Gans, Knox, & Croson, 2007; Groß et al., 2008), mostly in “multi-armed bandit” problems in which individuals attempt to maximize their payoffs from multiple gambles with initially unknown reward distributions. However, previous research on the exploration–exploitation tradeoff has largely ignored a real-world search cost that dramatically changes how organisms behave: the impact of competition during search. Although search affords more information about available options, it also increases the risk that good option(s) will be taken by competitors.

In this article, we research how competition affects pre-decisional exploration from a descriptive as well as a normative perspective. The essence of what we study concerns supply and demand. In a solitary environment, the “supply,” that is, the number of options available to choose from, is stable. It cannot be affected by the actions of others. Hence, a solitary decision maker can engage in extensive exploration, allowing her to carefully separate good from bad options at leisure before making a consequential choice. In contrast, in a competitive environment, “demand” increases and the danger lurks that competitors will claim desirable options, leaving the thoroughly exploring decision maker with an inferior option set to choose from. With the increased tension between exploration

and exploitation driven by competition, decision makers might be best advised to choose as soon as they detect an option that is likely to be good enough. But when does that moment come? Does search under competition indeed become as truncated as the crab's shell search and the shopper's television search suggest and, if so, how good or bad are the resulting choices? To address these questions, we take advantage of an experimental tool that has recently been used to study the process of search in a range of solitary choice situations (Erev & Barron, 2005; Hertwig, Barron, Weber, & Erev, 2004; Weber, Shafir, & Blais, 2004): the sampling paradigm from research on decisions from experience (Hertwig & Erev, 2009). In this paradigm, participants explore options with a priori unknown underlying probability distributions before deciding between them (exploration before exploitation). In the present research, we pit a solitary variant of this paradigm against a novel competitive variant that we call the *competitive sampling game*.

1.1. Decisions from experience

In the sampling paradigm, a solitary player learns about (i.e. explores) options with a priori unknown payoff distributions that differ in value by sampling outcomes for as long as she wishes, without financial cost. When ready, she chooses (i.e. exploits) her preferred option on the basis of her sampling experience. This final choice then results in a real financial consequence, such as a random payment drawn from the option's payoff distribution. Since the information decision-makers gain through sampling reduces uncertainty about options and increases the likelihood of choosing good over bad options, a key measure in the sampling paradigm is how long people search for information before making a choice. Given that sampling has no cost other than time, one might expect solitary choosers to sample extensively, but previous research shows that protracted search is not the norm. Across studies, participants have generally been found to take between 11 and 19 draws, or about 7 ± 2 samples per option before making a final choice between two gambles (for a review, see Hertwig, *in press*). Researchers have proposed several reasons why people do not search extensively in solitary choice: small sample statistics can be quite accurate where differences are large enough to matter (Johnson, Budescu, & Wallsten, 2001), frugal search reduces choice difficulty (Hertwig & Pleskac, 2010), short-term maximization goals prompt limited search (Wulff, Hills, & Hertwig, 2014), short-term memory constrains information use, and opportunity costs mount as search continues (Hertwig, *in press*).

1.2. The Competitive Sampling Game (CSG)

In this paper we introduce a competitive variant of the sampling paradigm called the competitive sampling game. In the game, players choose between two options realized as urns on the computer screen. Each urn contains 100 virtual balls, with each ball bearing a number. The distribution of numbers in an urn dictates its value. Before making a final consequential choice, players have the

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