

Present bias in exploratory choice

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Abstract

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The problem of under-exploration seems remarkably common. One of the most severe expressions of under-exploration is learned helplessness, in which an organism experiences the absence of control over the environment, learns that the environment is uncontrollable, and thus ceases to take actions that might allow it to regain its sense of control. Learned helplessness has been proposed to underlie most notably depression (Abramson et al. (1978, 1989) but also problems ranging from difficulties in school to poverty (CITE).

While the cognitive appraisal of experienced events affects the development of learned helplessness (Abramson et al., 1978), patterns of exploration clearly play a role as well (Huys & Dayan, 2009; Teodorescu & Erev, 2014a). In the case of depression, interventions aimed at increasing the exploration of activities this might produce a sense of pleasure and mastery have been found to be as effective as those with a more cognitive orientation (Jacobson et al., 1996).

Under-exploration also seems to occur in the development of complex skills, such as flying a plane or playing a sport (CITE). In these settings, an “emphasis change” training method in which the focus of practice is repeatedly changed can lead to greater performance gains than unguided practice or more complex training methods. Emphasis change works because it encourages people to continually explore the performance space to find more effective cognitive and motor routines (CITE). Without these interventions, people often enter a “local maximum” in which exploration decreases and performance plateaus (CITE).

There are many other areas in which under-exploration is less clearly established, but is suspected to play a role in maladaptive behavior. Insufficient exploratory interaction with outgroups may be one cause of stereotypes and prejudice (Denrell, 2005), and interventions that increase intergroup contact reduce stereotypes (Shook & Fazio, 2008). The crowding out of exploration by exploitation is a concern in organizational behavior as well (March (1991); Levinthal & March (1993), prompting research into organizational structures that may preserve exploration (Fang et al., 2010).

Under- and over-exploration in the lab

Given the seeming pervasiveness of under-exploration in real-world decision making, one might expect a clear pattern of under-exploration in lab experiments. Instead, however, lab results are mixed, with people sometimes under-exploring, sometimes over-exploring, and sometimes exploring close

to an optimal amount. To take two illustrative examples, Zwick et al. (2003) found that in a sequential search task people under-searched when there were no information costs but over-searched when there were information costs, and Teodorescu & Erev (2014b) found that people explored unknown alternatives too often or not often enough depending on whether rare outcomes were positive or negative. Similar results have been obtained within and across a variety of other studies and paradigms (Tversky & Edwards, 1966; Bussemeyer & Rapoport, 1988; Hertwig et al., 2004; Navarro et al., 2016; Juni et al., 2016; Sang et al., 2011).

These experimental studies raise the question of why under-exploration appears more widespread than over-exploration in the field, but not in the lab. One possibility is that both forms of deviation from optimality are in fact prevalent, though perhaps in different settings, and that the seemingly general bias toward under-exploration is illusory. However, in the current paper we propose instead that lab tests of exploratory choice have been missing a key component of real-world exploratory choice, namely, the distribution of choices and outcomes over time, and that this spreading of exploratory choices over time may account for the tendency to under-explore.

Exploration and myopia

Under-exploration is often proposed to be the result of myopia: the underweighting of temporally distant rewards relative to close ones (March (1991); Levinthal & March (1993). While choosing actions that are expected to immediately maximize reward is inherently exploitative, exploration often requires the decision-maker to suffer short-term costs in search of better future options.

There are two distinct possible causes of myopia (Bartels & Urminsky, 2015). The first is that the decision-maker is unaware of or fails to consider the future. This form of myopia is likely one cause of under-exploration, particularly in complex environments. However, researchers in exploratory choice have begun to address this form of myopia, and have found that people change their patterns of exploration based on their expectations about future choices, showing that, at least to some degree they do consider the future (Meyer & Shi, 1995; Wilson et al., 2014; Rich & Gureckis, 2017).

The second form of myopia is that the decision-maker is aware of the future but simply doesn't care as much about it. A wealth of studies have shown that this form of myopia is an important factor in human decision making, and that people are strongly biased towards present. For example, people will often prefer a larger, later monetary reward to a smaller, sooner reward when both rewards are in the fu-

ture. But when the time until both rewards is reduced so that the sooner reward is immediate, the sooner reward seems to loom larger and people may switch their preference (Kirby & Herrnstein, 1995). With non-monetary rewards, such as the cessation of an annoying noise (Solnick et al., 1980), watching a video when bored (Navarick, 1998), or drinking soda when thirsty (Brown et al., 2009), a bias towards immediate rewards has been observed on the scale of minutes or even seconds.

Present bias has the clear potential to cause people to explore too little, by increasing the perceived immediate gains of exploiting relative to the delayed gains of exploring. However, to date there has been no experimental research examining how people's bias towards the present affects exploratory choice. In part, this is a product of limits in experiment design. In most exploratory choice experiments, each choice and outcome takes fewer than 10 seconds to complete, making it unlikely for a large bias to develop between the current trial and future ones. More importantly, regardless of the length of each trial, rewards are generally not consumed on a trial-by-trial basis. For example, a participant might receive "points" on each trial, which are converted to money when the experiment ends. In this sort of paradigm, there is no reason to expect a bias towards the present choice's rewards over future rewards, as all rewards are in fact delivered at the same time.

In the present study, we seek to address the lack of research on present bias and exploratory choice. We develop a novel exploratory choice task using real consumption rewards, and compare behavior when the outcome of each choice is consumed immediately to behavior when outcomes are temporally delayed.

Experiment

Method

Participants.

Design and procedure. Participants were informed that their job was to perform a monotonous slider task that would be split into 30-second "work periods", but that they would be able to make choices throughout the experiment that would give them a chance to watch a Youtube video instead. The number of remaining work periods in the experiment was shown at the top of the screen, as was the number of seconds left in the current work period.

The slider task was based of a task previously used by Gill & Prowse (2012). In each period of the slider task, five horizontal sliders appeared on the screen. Each started at a random setting between 0 and 100, with the slider's value shown to its right, with a random horizontal offset so that the sliders were not aligned. The participant's task was to use the mouse to move each slider to "50" before the work period ended. When a participant released the mouse at the correct setting, the slider turned green to show it had been completed. To ensure that the task took close to the allotted 30 seconds, at the beginning of the task only the top slider was enabled, and

the other four were grayed out. Additional sliders were enabled at five-second intervals, such that all five sliders were available after 20 seconds.

Before beginning the experiment, participants chose one of four videos available on Youtube: an episode of "Planet Earth", and episode of "The Great British Bakeoff", and episode of "Mythbusters", or an Ellen Degeneres comedy special. The video was embedded in the experiment with all user controls (such as skipping ahead) disabled. When given access to the video, participants had to keep the browser window open and hold down the space bar for the video to play. This allowed us to ensure that participants maintained engagement with the content.

In the main part of the experiment, participants completed a total of 70 work periods. For the first 10 (in the immediate condition) or 6 (in the delayed condition) work periods, participants simply clicked a button to begin the slider task. After these initial periods, participants gained access to six "machines", each of which had a "current spinner" and a "new spinner". Before each work period, participants clicked the circled machine, were shown the machine and made a choice about which spinner to run. Based on their choices, there was a chance the machine would perform the work task for the participant, allowing the participant to watch their chosen video instead.

In the immediate condition, the machine ran immediately after the choice was made, and affected the next work period. It then "cooled off" for the following five periods, as choices were made with the other five machines.

In the delayed condition, the machine had to "process" for four work periods after a choice was made, thus delaying the outcome by least 2 minutes. The participant then clicked the machine again to return to it and observe its outcome, and either perform the slider task or watch the video. The machine then cooled off for a single period before being ready for another choice. In the first four periods in which machines were available in the delayed condition, participants made a choice but then simply pressed a button to begin the slider task (as no machine had yet finished processing). In the final four periods, participants observed the outcomes of the machines but made no more choices.

At each choice, participants had to select between two options: run the machine's "current spinner" or run a "new spinner". Each machine had two circular spinners with arrows at the top. The current spinner was split into five black and five gold wedges. If a participant chose the current spinner, it spun (immediately or after four periods, depending on the condition) and, if the arrow landed on the gold wedge, the machine worked and the participant could watch the video. Initially, the current spinner's gold wedges were randomly set for each machine to cover between 1/3 and 2/3 of the spinner.

The new spinner initially showed a question mark. If a participant chose the new spinner, then (immediately or after four periods) a new spinner was created and appeared on the machine. The new spinner's gold wedges could cover any-

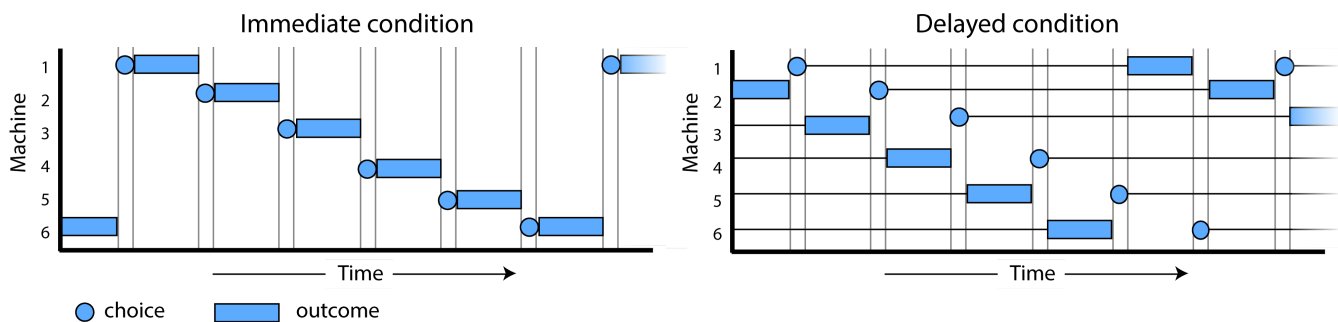


Figure 1: A schematic illustration of the two conditions. In both conditions, six 30-second work periods pass between consecutive choices with a given machine. In the immediate condition (left), the outcome for a choice is revealed and occurs immediately after the choice is made. In the delayed condition (right), the outcome of a choice is revealed and occurs after a delay of four work periods.

where from 0% of the spinner to 100% of the spinner. The new spinner then spun and, if the arrow landed on a gold wedge, the machine worked. Additionally, if the new spinner had a greater gold area than the current spinner, the new spinner was “saved” and the current spinner was updated to the new spinner. This meant that while choosing a new spinner carried some risk, it also carried long-term benefits as the current spinner could be improved from its initial value.

Finally, in order to induce exploration throughout the entire experiment, the six machines would occasionally “reset” after they ran. When this occurred, the current spinner would be set to a new random value between 1/3 and 2/3 gold. Participants were informed that this would occur randomly on 1/6 of trials. In fact, the procedure was designed so exactly one of the six machines would reset on each cycle through the machines, and no machine would be reset on two consecutive uses.

During the machine choices, participants had access to an “info” button at the bottom of the screen that provided reminders about the dynamics of the task. In addition, before beginning the full experiment, participants completed two practice phase. First, they performed several trials of practice using the machines, with the actual work periods removed. Then, they performed three work periods practicing the slider task.

Participants were given a performance-based bonus of \$3.00 for completing the slider tasks accurately. If they missed fewer than 10% of sliders throughout the experiment and left the video paused less than 20% of the time, they were not penalized. However, if they missed more sliders or left the video paused for longer, they lose 10 cents from their bonus for each additional percentage of sliders missed or time with the video paused. The running percentage of sliders missed and video pause time was displayed at the top of the screen throughout the experiment.

Acknowledgments

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