Online Shopping as Foraging: The Effects of Increasing Delays on Purchasing and Patch Residence

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Abstract—*This paper extends the Behavioral Ecology of Consumption, a foraging theory model of human decision-making in an online environment, in a replication and extension of previous online foraging research. Participants shopped for music CDs in a simulated internet mall featuring five virtual music stores with delay to in-stock feedback of 2, 4, 8, 16, and 32 seconds. Preference was measured as the proportion of total purchases and shopping time allocated to each store. Consistent with previous research, a hyperbolic decay function provided the best fit to the data. The results further the consumer foraging model and bolster existing evidence of the generality of hyperbolic discounting and matching in human decision-making.*

Index Terms—*Behavioral ecology, consumer behavior, delay discounting, foraging theory, matching.*

Resources are scarce and stochastic in the natural environment. Survival and reproduction pressures favor those organisms that can most efficiently exploit the environment, or forage most optimally. Foraging research boasts an impressive amount of data and theory, illuminating understanding of choice in uncertain environments [1]. Although foraging theory was built on studies of nonhuman animals, later research demonstrates that the fundamental findings and formal models of foraging theory generalize to human behavior as well (see [2] and [3] for reviews). Findings from human foraging research parallel results from analogous studies with nonhuman participants, as evidenced by data obtained through anthropological fieldwork with indigenous peoples [4]–[7] and data obtained in quantitative studies of supermarket shopping in the UK [8]–[10]. Turning to an electronic environment, the empirical relationships described in recent foraging research with humans account for such diverse behaviors as acquiring reference materials in libraries [11], searching for information online [12]–[15], and shopping for music on the internet [16]–[18].

These latter online shopping studies provide a bridge between e-commerce research and Darwinian theory. According to some theorists, human consumption should be treated as a bio-behavioral phenomenon, in which consumer decision-making is governed by behavioral adaptations shaped in ancestral environments [19]–[22]. Toward this end, a recent theory of consumer behavior, termed the BEHAVIORAL ECOLOGY OF CONSUMPTION, posits that the temporal phases of foraging activities, as described by Lea [23], are mirrored in human consumer behavior [24]. Consumption decisions refer to the ongoing exchange of behavior and time for basic commodities that organisms must acquire from their environments [25]. In this sense, consuming organisms can be regarded as decision-makers who are constantly executing economic transactions with their environments. Because most organisms devote the majority of their time and energy to acquiring resources, it has been argued that a majority of behavior is fundamentally economic in nature [26]. This economic operationalization of behavior is the conceptual foundation for foraging theory in behavioral ecology. Foraging theory models the economic interface between organism and environment, such that individual fitness is evaluated in terms of the ratio of energy taken in to time spent foraging for a commodity [1], [27]–[29].

DELAY AND HANDLING TIME

Time, and specifically the amount of time, between an allotted decision and an intended outcome is central to our generalization of foraging to an e-commerce environment. Foraging theory delineates three major phases of foraging, namely searching, handling, and consumption [1]. In establishing an evolutionary account of the effects of delay on consumer decision-making, the handling phase is a conceptual centerpiece [23]. In foraging theory, HANDLING denotes time and energy devoted to a prey item after it has already been acquired or captured and before any energy can be derived from it. For organisms that exploit patches, this might involve cracking the shell of a seed or nut; for predators, this might involve transporting a prey item to a safe location and cleaning it before

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consumption. It is important to note that handling does not guarantee consumption; the prey item may be abandoned or lost during handling. A nut or other food item may be dropped or discarded during shelling; a prey animal may escape a carnivore after a capture response is emitted. In laboratory-based studies of foraging, handling time is usually modeled as a delay between a terminal response and delivery or nondelivery of a food item (e.g., [2]). Thus, handling time contributes to the total delay to energy intake or reinforcement. All other things being equal, a food item associated with a longer handling time is less preferable than an item that is less time intensive [30]. For foragers, delay can be deadly.

Delay is also a common vexation in online environments, and it represents a primary source of internet user frustration [31], [32]. Download delay is significantly negatively correlated with website success [33], and it reduces learning and student satisfaction in online learning [34]. In e-commerce, download delay is related to negative attitudes towards e-tailers and their websites [35]–[38], and is inversely related to purchases and affective reactions to online stores [16], [18]. Delay will remain a fixture in the online world for the foreseeable future. According to The Pew Internet & American Life Project [39], the majority of adults in the US do not have a broadband connection at home, 22% have a dialup connection, and the majority of these dialup users say they are not interested in switching to a broadband connection. Internet users in developing countries are expected to be even more subject to online delay as the information infrastructure in these countries lags behind that of developed countries [37]. Online delays will not disappear anytime soon.

HYPERBOLIC DISCOUNTING

Behavioral economists have observed that discounting implicit in human intertemporal choices are generally well described by a hyperbolic decay function as

$$V = A/(1 + kD) \qquad (1)$$

where a reward/outcome of amount A, available after a delay period D, has a present subjective value of V and parameter k describes how steeply the value of the delayed amount is discounted [40]. This hyperbolic function is sharply bowed in comparison to the exponential discount function that is commonly invoked to characterize delay-reduction effects in economics [41], [42]. With a hyperbolic function, as delay time increases, the value of the reward drops precipitously at first, and more gradually over time. One interesting byproduct of the shape of this discount function is that smaller, less desirable outcomes are sometimes preferred to larger, superior outcomes, such as when we decide to withdraw money from an ATM charging a $2.00 fee even though the funds could be had free of charge from our own bank located just a few blocks away. Such discounting is regarded as a fundamental characteristic of any decision where rewards are delivered after some delay and has been found repeatedly across species, across different commodities ranging from food to money to health outcomes, and across tasks (see [43] for a review).

In foraging theory, TIME DISCOUNTING is regarded as a foraging rule, or behavioral heuristic, which influences the efficiency of a forager's decision-making and time allocation [1], [7], [44]–[46]. For example, the decision to remain in a patch (a term referring to a location with a certain density of prey items) is continuously pitted against the potentially greater rewards available in another patch that is some unknown distance away. Prey items with shorter handling times are generally preferred to those associated with greater investments of time. Naturally, as the density of food drops in one patch, the time between food items increases. Beyond a certain inter-item time threshold, the forager may prefer to move to a new patch where the food density could be greater. As such, over time, a forager's patch selections should be distributed in relative proportion to the mean within-patch delay time between prey items. Thus, when time discounting operates as a foraging rule it models the proportionate distribution of a series of choices that will be allocated to several response alternatives, as predicted by the matching law [47], [48].

FORAGING ONLINE AND INCREASING DELAYS: REASONS FOR REPLICATION

The current research serves two functions, the first of which concerns basic theory generalization. The present work is based upon a synthesis of Darwinian theory, foraging theory, and delay discounting, all of which were initially developed through research with nonhuman animals. In its application to a human consumer environment, the current work intends to expand the generality of these interlocking theories. Specifically, we extend the work in temporal discounting by testing the viability of the hyperbolic discount function in a more applied context with a new set of parameters. Although the hyperbolic discount function is well established through decades of research [40]–[43], [47], [48], its extension to more applied decisions such as online shopping is still nascent. The two previous studies of delay discounting in online shopping obtained good fits to the hypothesized hyperbolic function ($R^2 = 0.95$ [16]; $R^2 = 0.76$ [18]); however, they used delay values (0.5, 2 ,4, 8, 16 seconds) that may not be as representative of the delays experienced by many online consumers. That is, these delays may be too short in contrast to the delays that occur in typical e-commerce. In usability studies, Selvidge used up to 60-second delays [31], in a later study Selvidge found delay times up to 151 seconds [56], and Chen reported that the average delay to download a homepage for American users was 32 seconds using a connection with a 28.8-K bit/sec modem [57], but given the annual double-digit increases in broadband growth, Chen's estimates may now be overstated.

The second function of the work is to systematically replicate and extend the generality of the findings from DiClemente and Hantula on the effects of delay on foraging in a simulated online mall [16]. Replication is a central feature of scientific research and it is especially important in the present case where establishing stable quantitative relationships between variables is at issue [49]. In the present case, DiClemente and Hantula used the same delay values as Rajala and Hantula [18]; and while these two studies are part of a systematic research program, it is possible that the delay values used in and of themselves may have contributed to artifactual results. That is, the results may have been idiosyncratic to the delay values used. In empirical research terminology, an artifact is a systematic error in an experiment or series of experiments that may jeopardize the inferences and conclusions drawn. In behavioral research with humans, the experimental artifact has been long recognized as a critical issue in research methodology [50] and remains a subject of discussion and debate [51], [52]. Replication, especially systematic replication using varying participants and parameters, is the most basic control for artifacts. Historically, replication of findings has been rare in consumer behavior research [53]. Given that consumer behavior is both socially and contextually influenced, replication in this domain takes on additional importance as findings can be artifacts of a particular social or physical context (see, e.g., [54]). Finally, although delay is ever-present online, the effects of delay are poorly understood with some confounding results [36], [55]. With confounding results already seen, replication is necessary to be sure prior positive results reflect more than statistical noise.

For the current replication, it is hypothesized that the relationship between delay and store preference should be the same patterns of preference that emerged with previous research [16], [18], corresponding to the hyperbolic decay function in (1) [40].

METHOD

Participants Twenty undergraduate students from the general campus population of a public urban university representing a diverse mix of class year and age (10 men, 10 women, mean age = 20.8 years, range 18–32 years) volunteered for chances in a lottery drawing for free music CDs. All participants reported substantial internet use and had made at least one online purchase in the preceding month.

Apparatus and Procedure Participants worked on IBM-PC compatible computers with a color monitor, a keyboard, and mouse programmed in VisualBASIC to present the Microworld [53] used in the ascending clock condition of [16]. The screen display had icons for five online CD stores arranged pentagonally. A time online clock ran continuously and was displayed in the upper right corner of the screen.

As a replication and extension of [16], precisely the same procedures were used, except that the delay to in-stock feedback values were longer. Participants shopped for CDs in a simulated online mall. Clicking on a store icon would allow the shopper to enter the store (analogous to a food patch) and then search for a particular CD (searching within a patch). After the CD information was entered, the store would check to see if the CD was in stock. If the CD was in stock the shopper could elect to purchase it or not. After each search, whether successful or not, the shopper could stay in the store or return to the five-store screen to select another store (travel time). The experiment ended when 120 CDs were purchased. The following parameters were used in the experiment:

Travel Time There was no programmed delay in the time to exit a store, return to the five-store screen, or enter another store. Any delay was a random function of system response time and user mouse click latency.

In-Stock Probability The in-stock probability for the CDs was held constant at 0.80.

Pricing CD prices ranged from $11.98 to $14.98 USD. The prices of the different CDs varied

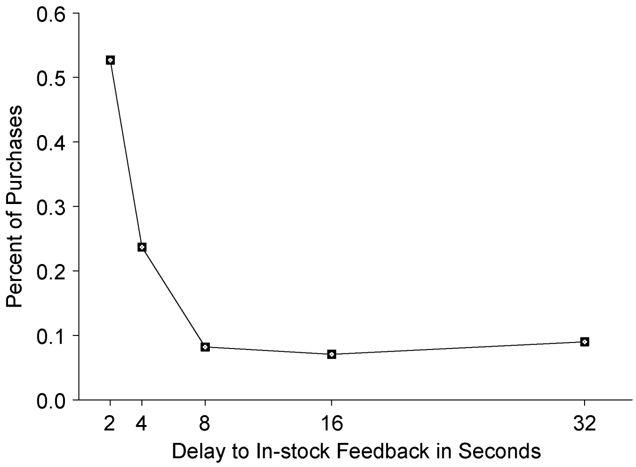

Fig. 1. Percent of purchases as a function of delay to in-stock feedback.

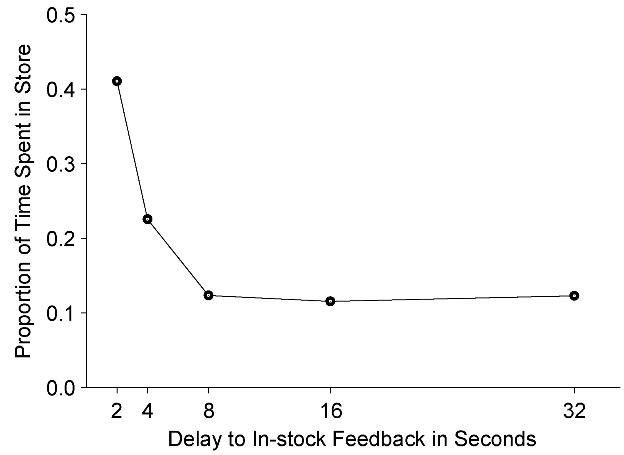

Fig. 2. Proportion of time spent in each store as a function of delay to in-stock feedback.

randomly, but the price was held constant for any individual CD among all of the stores; no store had any price advantage (for example if Yngwie Malmsteen's *Rising Force* CD was $12.98 in one store for an individual participant it would be $12.98 in all stores for that participant; however, it could be a different price for a different participant; similarly Jam Lab's *extended_play* CD may have been $11.98 for that same participant but priced differently for another participant).

Delay to In-Stock Feedback This delay was the independent variable in the experiment. Each store had a delay of 2, 4, 8, 16, or 32 seconds between the click after selecting the CD and the message indicating if the store had the CD in stock. This delay remained constant for each store throughout the experiment but was randomly assigned to stores for each participant.

RESULTS

Data from one participant were lost due to a computer disk error so all results are based on the responses of 19 participants. In keeping with previous research [16]–[18], purchase data are presented. In addition, because patch residence time is a theoretically important variable in foraging research [1], [27], time allocation data are also presented.

Purchases Percent of CDs purchased per store is plotted as a function of delay to in-stock feedback in Fig. 1. As can be seen from Fig. 1, the purchase data are curvilinear and conform to the hyperbolic decay function of (1) ($R^2 = .96$).

Time Allocation Percent of time spent in each store is plotted as a function of delay to in-stock feedback in Fig. 2. As can be seen from Fig. 2, the time allocation data are curvilinear and conform to a hyperbolic decay function of (1) ($R^2 = .85$). The data also show evidence of exhaustive patch sampling as all stores were visited throughout the foraging episode and each store occupied at least 10% of foraging time.

DISCUSSION

Both purchase and time allocation (patch residence) data are well described by the predicted hyperbolic decay function with greater than 80% of the variance accounted for by (1). Although the delay values were an order of magnitude greater than those used in previous research, the purchase data replicate previous findings [16], [18] and further the validity of the application of the discounting heuristic in analog foraging activities. In particular, the present study used the ascending clock condition of [16] and obtained a fit of 0.96 to function in (1) which is nearly identical to the 0.95 fit found in the previous experiment. The time allocation data are also consistent with predictions from foraging theory. It may seem ironic that a primordial behavioral adaptation, such as hyperbolic decay, fits so well within such an advanced high-tech environment as the internet. However, when viewed in conjunction with present day research on information foraging [11]–[14] and biologically informed adaptation to virtual communication and teamwork [58]–[64], the veracity of a Darwinian perspective on technologically intensive behavior becomes very compelling.

An extensive literature on intertemporal choice supports the ubiquity of the hyperbolic discount function (see [43] for a review). Ainslie has argued that humans are biologically prepared to discount rewards in this fashion [41]. Further, behavioral ecologists suggest that discounting serves as a foraging rule, assisting organisms in making appropriate feeding and patch departure decisions [29], [44], [45]. Underlying these discussions is the premise that hyperbolic discounting is an evolved mechanism for economic decision-making, which emerges naturally in ecologically relevant contexts (see also [65] and [66]), that the hyperbolic pattern appeared in the present context is an interesting illustration of Ainslie's notion of biological preparedness [41]. The data in the current study fit the hyperbolic discount well, and this in turn suggests that the present experimental Microworld [67] constitutes an ecologically valid context for many human consumers who have become increasingly accustomed to internet shopping.

These results may also illuminate some other aspects of delay. In information systems, delays merely seconds long are frustrating [32], represent a major component of negative evaluations of websites [33], and are detrimental to learning and satisfaction in online instruction [34]. E-commerce research shows that online delays are associated with negative attitudes towards e-tailers [35], [37], [38] (although this effect is mediated by cultural orientations toward time), and also that delayed delivery times for items ordered online are strongly ill-favored [68]. In the natural environment, anything delayed may be denied. A strong preference for immediate payoffs (and a complementary avoidance of delayed payoffs) may well be a strongly selected survival strategy [41]. Indeed, Critchfield and Atteberry showed that individuals who are steep temporal discounters are the more successful foragers in a competitive foraging task [44].

It is important to note that participants did not display exclusive preference for the store with the shortest delay, but rather they spent time and made purchases in all stores, consistent with foraging research, and the matching law specifically. From a classical economic perspective this behavior would appear to be irrational, as a strict maximization model would dictate staying in the store with the shortest delay. However, as Herrnstein points out, while such maximization may be a good prescriptive strategy it is not a particularly accurate description of behavior observed across a wide range of species [47]. Rather, MATCHING, or a rough correspondence between behavior, choice, time allocation, and outcome/payoff, is generally observed. Minimizing delays, as seen in the present study, leads to matching [2], [48]. From a Darwinian perspective, matching makes long-term sense. A maximization strategy may work well in the short term, but if the patch in which the organism has exclusively foraged becomes depleted or destroyed then that forager might soon perish with no exposure to alternative resources. On the other hand, a forager that matches may not always exploit a patch to its fullest, but by traveling between and sampling different patches, a matching forager will have options if a patch is depleted or destroyed. Given the competitive and stochastic nature of foraging in the natural environment and the extent to which a genetic basis for matching may be passed on to future generations, and its generality across species, it seems plausible that matching might have a genetic basis. Humans may have now evolved the cultural, linguistic, and mathematical practices that enable us to develop such concepts as maximization and economic rationality, but we have not evolved away from our more basic and fundamental nature; or to paraphrase Kock [59], we are the apes who use e-commerce.

The present study was an experiment, which is appropriate for a theory-testing exercise, using young adults who were appropriate test subjects because they are the major consumers of music online. This study, like its predecessors, was conducted in a simulated online mall. The hypothetical money used in the study was not earned by the participants, nor were the CDs they purchased real. Ultimately, it might be concluded that the CDs did not matter to the participants, and that they were simply adhering to textual instructions presented at the outset of the study. Though these concerns are valid, two important methodological findings from recent literature attenuate this broad concern. First, a number of studies (e.g., [69], [70]–[72]) have found remarkably high correlations between observed discounting of real and hypothetical rewards. Second, the environment that the participants interacted with in the current paper has been shown to be psychologically engaging [18]. As DiFonzo noted, the contingencies of interacting with such environments can often be quite realistic [67]. Given the extensive exposure that modern humans have to computer-based environments through the internet and video games, the context of the present study should have been salient and familiar to the participants, and thus more likely to elicit normative patterns of decision-making. Though the methodological merits of Microworld environments have been described in detail elsewhere [67], it is worth noting that psychological and mundane realism are known to be two of their defining characteristics. Overall, when evaluating the manipulations used in the current study, the critical test is not the characteristics of the manipulations themselves, but rather the data they produce.

While this study was designed primarily to test and advance theory, it suggests some insights for those who develop information systems and e-commerce sites. The most important point is that delay should be minimized. In both in-store [73] and in online shopping [16], [18], [35]–[38], delay is associated with negative attitudes and fewer purchases. Delay is discounted deeply, which seems to be more of a reflection of evolved preferences than of some sort of character flaw of impetuosity. In e-commerce, the race may go to the swiftest in a real sense. However, this is not to suggest that there is necessarily an absolute maximum tolerable delay time, but rather the discount function implies that delays are evaluated relative to others in the environment. In the present study, a 2-second delay was "shortest" and associated with the majority of purchases. However in DiClemente and Hantula's study, the store with the 2-second delay was not the shortest (0.5 seconds was) and as such accounted for approximately 20% of the purchases [16]. Another important applied implication is found in the store residence data. Contrary to what may be expected from a rational choice maximization perspective, participants in this study (and also in [16] and [18]) did not exhibit exclusive preference, but "patch sampled." For the store in the lead, the findings from this research are cautionary, as the shortest delay time (or any other competitive advantage) will not guarantee exclusive preference for extended periods. But, for a laggard store, these results may be optimistic, as consumers will continue to stray from the market leader, giving other e-tailers opportunities to capture them.

When communicating, working, searching, or consuming online, humans behave as they have for thousands of years. This amazing technologically advanced environment does not change the nature of the person interacting with it, but instead features of the online environment that most closely resemble features of long-lost ancestral environments evoke the same patterns of behavior that would have been found in the Pleistocene era. Technology changes in the blink of an eye, while evolutionary change is much more gradual. The present study joins a growing body of empirical research and theory showing that a thorough understanding of online behavior may be best built on Darwinian theory, and by extension the most useful online technologies will be those technologies that are designed with a full appreciation for the organism's evolved characteristics.

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