The Psychology of Consumer Decisions to Continue or Abandon Waits from Invisible

Service Queues

Narayan Janakiraman

Robert J. Meyer

Stephen J. Hoch[*]

Author Notes

Narayan Janakiraman is Assistant Professor of Marketing at the Eller College of Management, University of Arizona, 320L McClelland Hall, 1120 East Helen Street, Tucson, AZ, 85721, phone (520) 621-2885, fax (520) 621-7483, (narayan@eller.arizona.edu). Robert J. Meyer is the Gayfryd Steinberg Professor of Marketing at the Wharton School, University of Pennsylvania, Philadelphia, PA 19104 meyerr@wharton.upenn.edu, and Stephen J. Hoch is the John J. Pomerantz Professor of Marketing at the Wharton School, University of Pennsylvania, University of Pennsylvania, Philadelphia, PA 19104

Abstract

We examine the process by which consumers make sequential decisions whether to continue or abandon waits for service. We focus on the case of *invisible queues*, where consumers cannot observe their location in a queue as it progresses, only the passage of time. Our hypothesis is that stay-or-renege decisions will frequently sub-optimal, marked by a tendency to prematurely abandon waits from distributions for which it is never optimal to renege (e.g., uniform waits) but excessively persist given distributions that have optimal early reneging windows. We propose a competing-hazards theory that models on-going stay-or-renege decisions as a blend of two opposing influences: the escalating displeasure of waiting and the opposing desire to complete a wait that has been initiated. Among the theoretical predictions that emerge from this theory is that reneging rates will display an inverted *U*-shape function over time, with consumers being most prone to renege near the mid-point of waits. Reneging is also hypothesized to be affected by a number of normatively-irrelevant moderators, such as the initial number of alternative queues and the amount of physical activity that is engaged in during a wait. Evidence supporting these hypotheses is provided by four experimental studies in which respondents have the goal to complete as many downloads as possible from a hypothetical website within a finite time window, where there is a continuous opportunity to abandon a wait to begin a new one.

Decisions about whether to abandon waits form a ubiquitous part of consumer life. If one calls the cable company to request a repair and is put on hold, one faces a continuous stream of decisions whether to continue the wait--hoping that someone will soon come on the line--or abandon it, hoping that the wait will be shorter later. Although consumers may dismiss such stay-or-renege decisions as simply one of life's many annoyances, the economic stakes of their management can be substantial. To illustrate, anecdotal evidence from the banking industry suggests that nearly 50% of all calls are abandoned within 15 minutes of entering into a queue (Call Center Statistics 2002)—a rate of abandonment that could represent a substantial loss of potential business.

How efficient are consumers' intuitive stay-or-renege decisions? Surprisingly, the answer to this question is largely unknown. Although there exists a large literature that has studied how such decisions *should* be made by optimal agents (e.g., Mandelbaum and Shimkin 2000), and work that has examined the psychological processing of waiting times (e.g.., LeClerc, Schmitt, and Dube 1995; Zakay and Block 1996; Zhou and Soman 2003), comparatively little research has examined how such decisions are made or their efficiency relative to optimal benchmarks.

The purpose of this paper is to report the findings of a program of research aimed at gaining this knowledge. We report the results of a series of experiments that examine the ability of individuals to make decisions about whether to abandon queues with uncertain waiting times when there is an option to rejoin them later, as well as provide insights into the behavioral process that leads to these decisions.

The Psychology of Invisible Queues

In this work we examine how consumers solve a class of waiting problems that share the following structure. A consumer seeks a known reward (such as a realized web page or a completed phone call) that can be realized only after waiting in one of a number of alternative queues, each characterized by identical known waiting time distributions. The queues are assumed to be *invisible*, meaning that the consumer only observes the passage of time, not their location in the queue or the mechanism that might cause a wait to be short or long. An example might be a consumer who has been put on hold in a telephone queue and is unaware of the number of other customers who are also on hold. At any time after joining a queue the consumer has the option to abandon it and initiate a new wait at the same or alternative queue. If the wait is successfully completed, the consumer receives the reward and he or she has the opportunity to begin a new wait to receive another. The consumer's goal is to complete as many such successful waits as possible with an overall time budget.

While we are not aware of empirical work that has examined how individuals make such repeated stay-or-renege decisions, there is an extensive literature in operations management that describes at least how they *should* be made (e.g., Mandelbaum and Shimkin 2000). At the heart of normative analysis is the idea that queues should be rationally valued based on two considerations: the quality of the reward it offers upon completion and the time that will be spent awaiting that reward. Hence, if a consumer considers joining a queue that promises the reward $V(R)$ after an expected wait time t_0^*, its rational value would be the discounted expected utility $U=V(R)exp(-\beta t_0^*)$, where β is the consumer's temporal discount rate. Once a wait has been initiated, the consumer should remain in the queue as long as its updated discounted utility remains higher than that for starting a new wait; that is, as long as $\exp(-\beta(t_t^* - t)) > \exp(-\beta t_0^*)$,

where t_t^* is the consumer's updated belief about the likely time remaining given that t moments have elapsed in the queue. Note that since it will almost always be the case that $((t_t^* - t)$ will be non-increasing in t, the usual advice of normative theory is that if it is worthwhile to join a queue, it is worthwhile to stay in it.

How well would such a normative model describe actual waiting behavior? Anecdotal evidence is not encouraging. For example, according to the Florida department of corrections the vast majority of prison escapes occur among inmates in work-release centers who have less than eighteen months left on their sentence (Florida Department of Corrections 2002). What makes this statistic perplexing is that 91% of escapees are subsequently recaptured, and then must then serve an additional 2-3 years in a high-security facility. Although this example may be extreme, most people seem prone to similar violations of optimal waiting policies, such as abandoning a slow traffic lane on a freeway when we see the adjacent lane is momentarily moving faster—only to see cars in the lane we just abandoned accelerate past.

What might be the source of such inefficiencies in actual stay or bail decisions? Inefficiencies could arise from at least three potential sources: overly optimistic priors about the length of uncertain wait times, inefficiencies in time-versus-reward tradeoffs, and enhanced stress induced by ongoing waits.

Optimism in time expectations

Normative queuing theory presumes that individuals hold unbiased expectations about the likely length of the waits that they are about to encounter. One possible basis for excessive reneging from queues, however, would be if consumers believe that a given wait will be shorter than the actuarial mode or median. Given such beliefs, realized waits will often seem longer

than what is conjectured to be the case for new queues, hence fostering recurrent instincts to abandon.

There are two bases for hypothesizing such a bias. The first is the large body of work showing that intuitive forecasts of completion times for tasks are often overly optimistic, driven by a tendency for decision makers to construct estimates by focusing on scenarios that are *congruent* with a termination goal rather than *incongruent* (e.g., Buehler, Griffin, & Ross 1994; Newby-Clark, *et al* 2000). The optimism bias has been found to be quite robust, and persists even after base rates are made salient (Bryam 1997), the wait is perceived as controllable (Zakay, 1996), and when incentives are offered to respond accurately (Buehler *et al,* 1994).   While such studies have tended to focus on biases in estimates of the time required to complete plans rather than idle waits, the underlying mechanism might still apply. That is, when starting a wait consumers may be more likely to imagine scenarios that would lead to early termination (e.g., the line will suddenly speed up) rather than delayed completion (e.g., the line will suddenly stop).

A second basis is the tendency for human judges to believe that they will be "lucky" relative to others when subject to a probabilistic process that can have a negative outcome—in this case, a excessively long wait (e.g., Kahneman and Lovallo1993; Weinstein 1980; Weinstein and Klein 1996). Although most such demonstrations again come from different settings—for example, judging the personal risk of succumbing to a disease relative to a population—there is nevertheless an important parallel to queue choice: after making a choice from a set of queues (e.g., checkout lines), there is a risk of experiencing a wait that is much longer than the norm. The optimism bias would predict that while consumers may recognize that *someone*, by definition, must suffer a longer-than-average wait, it most likely *not* to be them. In other words,

consumers' personal estimate of the likely length of a wait will be closer to the *minimum* that might be expected across a set of queues rather than the median or mean.

Negative affect and stress: the emotional costs of waiting

A second potential source of inefficiency in stay-renege decisions is the heightened sense of displeasure and stress that waiting often triggers—particularly when waits are uncertain (e.g., Gelfand-Miller 2003; Taylor 1994). Such negative affect could lead to excessive abandonment of queues by two related mechanisms. The first is the simple desire to avoid actions or contexts that are a source of displeasure. Hence, one might leave a long line at a theme park on a hot day not out of a strategic belief that a much shorter wait could be obtained later, but simply because the disutility of remaining in the queue exceeds whatever pleasure its ultimate reward might provide.

The second mechanism is that the heightened negative affect may also make it more difficult to clearly imagine whether the ultimate reward is worth the wait. As noted by a number of authors, negative affect and/or stress often has a debilitating effect on decision making by constricting the breadth of cognitive processing that occurs during a task (e.g., Keinan, 1987; Luce, Bettman, and Payne 2001; Zackay 1993). Hence, for example, as the stress of continued waiting in a queue builds, consumers may find it hard to focus on anything *but* the sense of displeasure that the queue is inducing, ignoring such considerations as the possibility that one might later deem the wait worthwhile (if it were completed), or that a new wait would likely be just as long.

The counter-veiling effect of committed time

As strong as the urge might often be to abandon waits that have become unpleasant, it is also clear that such instincts often fight against the rational knowledge that, *ceteris paribus*, the

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value of staying in a queue increases as the expected time remaining decreases (expression 1). For example, in the same way that parents instinctively know that the best way to calm an impatient toddler on a long car ride is to promise that, "we're almost there", we conjecture that a guest at *Disney World* who has been waiting an hour for a ride would seem to be more loathe to abandon the queue if they knew that they were next in line as opposed to still having a 30-mninute wait ahead of them.

Note that in both of these examples what is driving the appeal of completing a wait is not a reluctance to abandon the time that has been invested, but rather the decrease in the temporal distance to the reward. This would be consistent with previous work showing that individuals tend to ignore sunk time when evaluating waits (e.g., Soman 2001)—a result that is quite different from that typically found for decisions involving sunk money (e.g., Thaler 1980).

A Theory of Reneging

The implications of the above research for stay-renege decisions can be summarized in Figure 1, which diagrams a proposed hypothesis about how various psychological factors combine to influence decisions of stay or renege. The central hypothesis is that ongoing assessments of the value of remaining in a queue reflect a blend of two opposing psychic forces:

1. The rational desire to remain in a queue the closer one comes to its ultimate completion; and

2. The countervailing desire to abandon queues for which the experienced wait has been found to be unpleasant.

The theory departs from normative treatments of waiting through the introduction of this second element, which serves to discount the value of the reward promised by a queue the longer one has had to wait for it. One of the key implications of this process is that consumers are predicted

to be most vulnerable to abandoning waits in the middle intervals of a queue—when sufficient time has elapsed for the disutility of waiting to become formidable, yet not enough for this disutility to be offset by the opposing desire to complete waits whose reward is close at hand.

To characterize this process more precisely, consider a consumer who faces a choice from among a set of identical queues, each yielding a common reward *V(R)* upon completion. The length of the wait in each queue is initially uncertain; the consumer only knows that it will be a random draw from a known distribution (e.g., a uniform) that has the subjective expectation t_0^*. Because the queues have identical priors, the initial choice among queues is assumed to be arbitrary.

As waits evolve in the queue its ongoing attractiveness is modeled as a function of two competing dynamic elements:

1. *Completion utility*, defined as the value of the reward discounted by a revised estimate of the most likely time remaining in the queue (t_t^*-t); and

2. *Waiting utility*, defines as the value of the reward discounted by the time that has *elapsed* in the queue.

Completion utility is the rational instinct to see queues as more valuable the closer one is to its anticipated end. Formally,

$$U_{completion} = V(R)F(t_t^* - t),\qquad\qquad (1)$$

where *F( )* is a (0,1, *F(0)*=1) bounded subjective discount function that is decreasing and concave over the expected time remaining. To illustrate, $F(t_t^* - t) = \exp{-\beta(t_t^* - t)}$ describes a consumer who follows rational exponential discounting. In contrast, *waiting utility* captures the less-rational urge to see rewards as being less worth waiting for the more unpleasant the experienced wait. We characterize this effect in terms of the *retrospective* subjective discounting model

$$U_{waiting} = V(R)G(t), \qquad\qquad (2)$$

where *G(t)* is similarly a (0,1, *G(0)=1*) bounded function decreasing in *t* that captures the rate at which the value of the ward is psychologically diminished as a function of the experienced displeasure of the wait.

Taken together, as waits progress utility of the incumbent queue at time *t* (U_t) is assumed to be convex combination of those these two forces. That is,

$$U_t = V(R)[kF(t_t^* - t) + (1-k)G(t)], \qquad\qquad (3)$$

k is a (0,1) bounded scaling constant that captures the degree to which a consumer values queues more in terms of the time that likely remains ($F(t_t^* - t)$) versus the time that has elapsed (*G(t)*).

Note that expression (3) departs from normative accounts of queue valuation by positing that the attractiveness of queues is driven not only by the likely amount of time left to their completion, but also by the experienced displeasure of the time that has been invested, an effect that we capture through the retrospective discount function *G(t)*. Unlike *F( )*, which is assumed to be a simple concave function of the expected time remaining, we assume that *G(t)* takes on a *Prospect-Theory*-like shape that is strongly concave around the prior expected wait t_0^* (Kahneman and Tversky 1979). That is, we assume

$$G(t) = v_1(t) - v_2(t - t_0^*), G(0)=1 \qquad\qquad (4)$$

where v_1 and v_2 are monotonically decreasing functions of *t* and $(t - t_0^*)$, where v_2 is steeper for $t > t_0^*$ (losses) than $t < t_0^*$ (gains). In other words, waits that are longer than initially expected are hypothesized to be marginally more unpleasant than waits that are shorter than expected.

Given expression (3), the choice to wait or not follows a simple process: at each point in time the consumer compares the updated discounted expected utility of the current queue, U_t,

with that of a new wait (U_0). If the utility of the current queue exceeds that of this referent, the wait will be continued. If not, the wait will be abandoned, and a new wait initiated in the new queue.

Implications

The hypothesized valuation process given by Expression (3) holds several important properties. First, it describes a waiting time-discounting process that subsumes optimal queue valuation as a special case—that where consumers are only forward-looking *(k=1)* and follow constant exponential discounting ($F(t_t^* - t) = \exp(-\beta F(t_t^* - t))$). Second, when *k<1* the model predicts that initial queue evaluations will have an optimism bias. Because at the start of a wait the forward-looking discount function $F(t_t^* - t)$ will to be at its smallest value while the retrospective function *G(t)* will be at its highest *(G(0)=1)*, consumers who value queues in terms of their experienced pleasure will tend to have a more positive assessment of its prospects than those who focus exclusively on the discounted value of time to completion. At the extreme, a consumer for whom *k=0* would be predicted to be a compulsive joiner and reneger; all queues would be seen as attractive before they are entered (each would be associated with the undiscounted valuation $U_0=V(R)$), but be seen as increasingly less attractive the longer they were endured, regardless of how close the actual end might be.

Third, the process yields the prediction that consumers will be most vulnerable to reneging during the middle intervals of a wait, when the displeasure of waiting has become acute (when $t>t_0^*$), yet the updated expected time remaining is large ($t_t^* \gg t$). As illustrated in Figure 2, this implies that empirically reneging rates would tend to display an inverted *U*-shape over time, with reneging being unlikely early in queues when the experience of waiting has yet to

become unpleasant, and late in queues when completion is judged likely to be close at hand. We summarize this idea in terms of the following formal hypothesis:

H1: The Effect of Wait Durations on Mean Reneging. The rate of reneging will follow an Inverse-U-shaped curve, increasing from the start of the wait to a threshold and then subsequently decreasing as the maximum possible wait approaches.

We should emphasize, of course, that the exact shape of the reneging-rate function will vary from context to context, depending on such considerations as how consumers update their beliefs about the likely remaining duration of the wait ($t_t^* - t$). For example, the model accommodates two well-known heuristic strategies for garnering increased patience in queues: either by fostering perpetual beliefs that the end is "right around the corner" (conveying beliefs that ($t_t^* - t$) is small even when it may not be), or setting overly-cautious initial expectations for the likely duration of a wait (conveying beliefs that t_0^* is larger than it may be, a belief that would insure that the retrospective discount function *G( )* is evaluated only the gain domain.

Will reneging rates be optimal? Expression (3) predicts that in most cases consumers' assessments of the ongoing value of remaining in a queue will *not* be the same as those that would be prescribed by a normative analysis. Specifically, note that at each point in time a consumer would abandon the current queue in favor of a new one if the discount factor applied to a new queue is lower (larger in absolute value) than that applied to a new one; that is, if $F(t_0^*) > [kF(t_t^* - t) + (1 - k)G(t)]$. As we noted earlier, if the consumer is fully rational in valuing queues (*k=1*) this inequality would rarely hold, since for most distributions the more one has been invested in a wait the shorter the expected time remaining. On the other hand, in the more general case where consumers devalue the current queue by the experienced disutility of waiting

(the case where $k<1$), this inequality could potentially arise more often than normatively prescribed, leading to cases of suboptimal reneging.

We might add that the hazard of reneging would be amplified if consumers entered queues with overly-optimistic beliefs about the likely duration of the coming waits (t_0^*)—a possibility suggested by previous work on subjective forecasts of completion times (e.g., Buehler, Griffin, & Ross 1994). The implication of expression (4) applied to optimistic priors is that consumers will frequently find themselves in the loss domain of the discount function (the region where $t > t_0^*$) as waits evolve. That is, that will find themselves sensing that the wait is "unusually long" both more often and earlier than they should—something that would induce excessive rates of reneging. Hence, implicit to the theory is the following hypothesis:

> **H 2: A mean tendency to abandon queues for which waiting is optimal**: When faced with waiting-time distributions where reneging is never optimal, consumers will display significantly higher rates of reneging.

But what about the case where reneging *is* optimal? Although perhaps less common, there will be some waiting-time distributions for which it will be optimal to renege early in a wait. A familiar example is the bimodal distribution of a traffic light that is prone to periodically breakage; once one waits longer than the typical wait, one is much more likely to conclude that it will *never* change than it will change at any moment. In such cases the current theory predicts that consumers who attend to the disutility of waiting would be prone to the opposite bias of *not* reneging when they should. Specifically, recall that when little time has elapsed in a queue the extent of discounting due to the experienced displeasure of waiting will be limited (i.e., *G(t)* will be large). Hence, the more consumers attend to this fact when valuing a current queue—the smaller *k*—the more this will tend to offset the otherwise discouraging knowledge that the likely

time to completion will be long (a small value of $F(t_t^* - t)$). Hence, in the case where

$(t_t^* - t) > t_0^*$, consumers who are influenced by both sources of discounting would have a higher

hazard of remaining in a queue longer than they should. In summary,

> **H2a: A tendency to initially stay too long in queues for which there is a short**
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> **optimal reneging window.** When faced with waiting-time distributions that offer a
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> window for optimal reneging after a short wait, consumers will renege at less than the
>
> optimal rate, and discover the wisdom of reneging only after it becomes optimal to stay.

Theoretical Moderators.

As formulated, expression (3) offers a general characterization of how queues are

evaluated over time, a process that is likely to be conditioned by a number of potential task

variables. For example, consider the possible effect of increasing the number of queues that a

consumer initially has to choose from—and can later renege to—in the course of a wait.

Although such a manipulation would have no normative effect on reneging behavior (since all

queues have the same priors), we suggest that such a manipulation might cause consumers to

increasingly contemplate "what might have been" in the course of a wait—particularly if it

lapses longer than expected (e.g, Carmon, Wertenbroch and Zeelenberg 2003)[1].

Such an effect would be manifested within expressions (3) and (4) by hypothesizing that

increases in the number of alternative queues will foster increasingly optimistic estimates about

the likely duration of new waits, t_0^*. Specifically, rather than believing that the most likely

duration of any new wait will be the mean of the wait-time distribution, consumers will tend to

believe that they will realize a wait that is closer to the expected *minimum* wait, a value that will

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[1] Such regret, of course, would not completely be without cause, since as the number of queues increases the greater the objective odds that one *could* have chosen a queue with a shorter wait. This knowledge, however, obviously has little normative relevance to the decision of whether or not one should abandon the current wait.

decrease with increases in the number of queues. In terms of expression (4), such a bias would accelerate the decrease in waiting utility over time by making it more likely that $t > t_0^*$ (the loss region of the discount function), thus increasing the hazard of reneging. Hence, we hypothesize:

> **H3: Number of alternative queues.** The empirical frequency of decisions to renege during sequential decisions about uncertain waits will increase with an increase in number of outside options.

Such a tendency to have overly optimistic priors for length of new waits would, of course, be mitigated consumers if consumers were provided with ongoing feedback about the *actual* duration of the unchosen queues. If consumers were to see that the wait would have been just as long had they not chosen the current queue, expectations about the duration of alternative waits would be adjusted upward, diminishing the appeal of a new wait. In contrast, if they see that the alternative wait would indeed have been shorter, this would simply serve to reconfirm the natural appeal held by foregone options described above. Hence,

> **H4: Observed duration of alternative queues.** Providing information that alternative waits will also incur a longer-than expected wait times will decrease reneging rates. While providing reciprocal information that alternative waits would have incurred shorter waits may increase reneging rates, this effect will be smaller due to the already high rates of reneging predicted when waits exceed expectations.

The theory also implies that the relative likelihood of reneging will be conditioned by task factors that either heighten or detract attention to the ongoing disutility of waiting (k). For example, one mechanism that might increase this weight (in (3), decrease k) is to provide consumers with external aids that emphasize the amount of time that has elapsed in a wait, such as a clock posted by an elevator. We conjecture that such aids will enhance the rate of reneging

by focusing attention on the ongoing (unpleasant) experience of waiting. Consistent with the old adage that "watched pots never boil", providing consumers with elapsed time information may make waits seem longer (Zakay 1993), heighten the apparent contrast between the experienced wait and the expected wait, and increase the ambient stress naturally associated with uncertain waits. We thus hypothesize:

> **H5: Salience of the elapsed wait.** When faced with sequential decisions about uncertain waits, the empirical frequency of decisions to renege will be higher when duration information about the elapsed wait is available than when otherwise.

Finally, one might also imagine task variables that suppress attention to the duress of waiting. One of the often cited reasons for the negative affect that often accompanies waits is that they trigger sensations that a valuable resource—time—is being wasted (Larson, 1987). As such, there is empirical evidence that the disutility of waiting can be diminished if individuals are given activities to engage in while in a queue, be it physical (e.g., walking) or mental (watching television or reading; Taylor, 1994). Not only does the mere presence of activity diminish perceptions of time waste, it also draws cognitive resources away from monitoring time, decreasing ongoing time estimates (Zakay, 1989). This suggests a fifth likely moderator of reneging decisions:

> **H6: Activity during wait**. Decisions to renege will be lower when there is activity during the wait than otherwise.

EMPIRICAL ANALYSIS

Overview

The above hypotheses were tested over the course of four experimental studies. The task setting was that of waiting for downloads from a set of hypothetical websites. Specifically, upon being seated in a computer lab, participants read the following cover story:

Welcome to the Single Click Game. The purpose of this game is to see how talented you are at shopping and time management. You have a limited period of 150 seconds within which you will need to load as many web pages as you possibly can. There are several browsers that you can use to load the page. To load a page you will need to choose a browser and click on the load button once to start loading the page. Here's what makes the game hard: loading each page can take varying and uncertain amounts of time.

After reading the opening instructions participants were led to a screen that showed them options as browsers. The game started as soon as one of the options was chosen. Only one of the options could be chosen and on choosing an option subjects were led to another screen. While waiting for the page to load the subject always had the option of stopping the load and returning back to the main screen. On completing a wait, either by terminating the wait prematurely or by completing the wait, subjects could start a new wait from the same set of browsers. Pretests indicated that a total budget time of 150 seconds was long enough to get multiple replications within subject, but was short enough to not induce boredom. To emphasize the temporal independence of draws from both of these distributions subjects where further advised that the time it took to load a page on any occasion would not depend on how long it took to load a page on any previous occasion.

We chose this context because of its ability to meet two design goals: it was sufficiently generic so as to allow the incorporation and manipulation of a wide range of task variables, but was also sufficiently realistic to the subject population (college students) to insure that decisions would be made using the same heuristics used to make stay-or-renege decisions in non-laboratory settings.

In each of the studies participants faced one of two waiting-time distributions: a uniform, where it was never optimal to renege, and long-tailed distribution, where there was an optimal reneging window early in the wait. These two distributions were described using the following instructions:

(Uniform case): *Wait load times for loading a webpage can be anywhere from 1 to 30 seconds with all times between 1 and 30 seconds being equally likely.*
        Or
(*Long-tailed case): Wait times for loading a webpage is as follows:*

Length(sec)	*Probability*
1-10	*55%*
11-30	*30%*
31-60	*15%*

Explanation: 55% of all page loads will take any value between 1 to 10 seconds, 30% of page loads any value between 11 to 30 seconds and 15% of page loads between 31 to 60 seconds

These two distributions allowed us to examine choice behavior in settings both where reneging was optimal and where it was not, as well as provide a view of choice behavior in the context of two distributions that are typically encountered in markets. Specifically, the long-tailed distribution captures processes that are prone to periodic breakage; for example, downloads from browsers where if a server does not respond in relatively short order, odds are it is down. In contrast, the uniform distribution captures processes where waits randomly vary over a continuous interval, such as phone queues where there are varying numbers of unobserved competing callers.

Study One

Experimental Design and Procedure

Subjects were 63 undergraduate students enrolled at a Northeast University who agreed to participate in the study as part of their regular course credit. Each participant completed four replicates of the two different waiting-time distributions (uniform and long-tailed) described above, with the order of presentation randomized. In addition to the distribution two other variables were manipulated:

1. *Salience of elapsed wait*: Hypothesis 3 states that providing duration information is likely to increase reneging. To test the hypothesis, half of the subjects saw a prominently-displayed clock that allowed them the opportunity to monitor their elapsed wait.

2. *Salience of outside options*: The salience of outside options was manipulated by varying the size of the choice set within subjects. Specifically, within each 150-second time block subjects could choose from among either two or twelve download sites, each with the same wait-time distribution, with the order of appearance being randomized.

To motivate performance and to ensure active participation the best three performances in the game were rewarded with cash prizes. Salience of elapsed duration was manipulated between

subjects, by displaying or not displaying a clock that kept track of elapsed duration of the current wait.

Participants completed the experiments at computer terminals in the University's behavioral research laboratory. The total duration of the experiments ranged from approximately 15 to 20 minutes, depending on the length of time before and between games. After completing the eight required games subjects were asked a series of debriefing questions that tapped their beliefs about the average waits associated with the various waiting-time distributions and the goal of the task. 90% of respondents indicated that the objective of the game was to maximize total page loads, and that there was a cash prize to awarded to the participant who was most efficient at this task.

Analysis and Results

The two waiting-time distributions faced by subjects has simple optimal policies: when faced with the uniform distribution they should never have reneged, since the conditional expected wait for any invested queue would have be shorter than the unconditional expected wait for a new one. In contrast the long-tailed distribution was marked by an optimal reneging window between the 6th and 8th seconds. That is, if a respondent waited more than six seconds for a download the optimal strategy would be to immediately renege and initiate a new wait. After eighteen seconds, however, it would no longer be optimal to renege.

Did subjects follow these policies? Perhaps not surprisingly, they did not. Subjects reneged on 25% of all waits drawn from a uniform distribution, and, reneged on 27% of waits drawn from a long-tailed distribution that had reached the 30th second—long after the optimal reneging window had passed. These proportions are significantly greater ($p<0.01$) than the 0% reneging rate that would be optimal in both cases, supporting *H2: A mean tendency to abandon queues for which waiting is optimal*. In contrast, subjects did *not* tend to renege in the case where

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it was optimal to do so: that of being in a six-to-eighteen-seconds wait window in a long tail distribution. In this case, only 41% abandoned the wait, a frequency less (p<0.01) than the100% optimum, offering support for *H2a: A tendency to initially stay too long in queues for which there is a short optimal reneging window.*

We might add that these suboptimal reneging rates had the effect of substantially diminishing the number of successful downloads that subjects were able to achieve in the available 150-second time window. Following the optimal policy for each distribution (never bail from a uniform; bail from a long tail if the waits is between 6 and 18 seconds), subjects should have been able to realize an average of 9.67 downloads per session for both the uniform and long-tailed distributions. The actual realization, however, was less than this: when faced with successive uniform distributions subjects realized an average of 6.86 downloads, while when faced with a long-tail distribution an average of 7.92 downloads.

Hypothesis 1 predicts that the odds of reneging would follow an Inverse-U function, increasing monotonically from start of wait till a threshold and then decreasing till termination. In Figure 3 we plot the observed hazard function for reneging over discrete time intervals during the derived by the *SAS* procedure *Proc Lifetest* (Allison 1995). The figure plots the mean probability of reneging at any second within the plotted time interval conditional on not having reneged or completed the wait prior to that point. As predicted, both curves display an inverted *U*-shape, with the conditional probability of reneging first increasing during a wait and then later decreasing, thus providing initial support for *H1*. To test the possibility that the variation over time plotted in the figure might have reflected chance variation in a constant hazard rate over time, we performed a chi-square test of the comparative fit of two survival models: an exponential, which assumes that hazard rates are constant over time, and a log-normal, which

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can allow the hazard function to take on the hypothesized *U*-shape (see Allison 1995). For both waiting-time distributions the log-normal provided a significantly better fit to the data (chi square *(LL(log-normal-exponential)=16.8* for the uniform case, *p<.001; -254 for* the long-tailed case, p<.001), thus rejecting a constant hazard hypothesis as a description of the data.

The data also offered support for *H4: Number of alternative queues*. When subjects could choose among 12 download options relative to 2 there was a significant increase in reneging for both types of distributions (Uniform -- from 23% to 26%; Fisher's exact test p=0.02 ; Long Tail -- from 29% to 33%, Fisher's exact test p<0.001). Likewise, the data also offered support for *H5: Salience of elapsed wait.* Specifically, when subjects viewed a clock that showed how much time they had waited the frequency of reneging significantly increased for both types of distribution (Uniform -- 17% to 32%, Fisher's exact tail test p=0.02 ; Long Tail -- 28% to 34%, Fisher's exact test p<0.001).

Tests for the equivalence of the survival functions under each condition also gave support for *H5*, though they were more equivocal in their support of *H3*. Specifically, log-rank and Wilcoxin tests of the survival functions under low and high time salience (*H5*) rejected a null hypothesis of homogeneity (log-rank χ^2 uniform=75.6; p<.001; χ^2 long-tail=22.38; p<.0001; Wilcoxin χ^2 uniform=71.61; p<.001; χ^2 long-tail=2.88; p=0.08). In contrast, these two tests were mixed in their support for *H5,* the effect of the number of outside options. The log-rank tests, which assumes parallel hazard functions, could reject the null hypothesis in the case of the uniform distribution (χ^2 =3.59; p=.05), but not the long-tailed distribution (χ^2 =1.12; p=.27). In contrast, the Wilcoxin test, which gives more weight to differences early in the event history, could reject the null hypothesis of equivalence for the long-tailed distribution (χ^2 =7.02; p<0.01), but not the uniform (χ^2 =1.12; p=.28).

One limitation of these tests of the effect of the number of outside options, however, is that they do not exploit the within-subject nature of the manipulation; i.e., the ability to control for individual differences in mean hazard rates. To account for this, we also tested *H3* by estimating a heterogeneous proportional-hazard model of the form,

$$\lambda_{ki}(t) = \lambda_{io}(t)\ \exp\{\beta S_{ki} + \beta'_{k}Z_{ki}(t)\}, \qquad t \geq 0 \qquad\qquad (6)$$

where $\lambda_{ki}(t)$ is the conditional probability of reneging at time *t* for respondent *i* given that they are experimental condition *k* (2 or 12 alternative queues), $\lambda_{io}(t)$ is an unspecified baseline hazard function for respondent i, S_{ki} is an indicator variable where $S_{ki} = 1$ if respondent *i* faces 12 outside queues and 0 otherwise, and $Z_{ki}(t)$ is a vector of time-varying covariates (Allison 1995). When specifying (6) we considered two such covariates: time left in the game (continuous variable between 0-150) and game number (continuous variable between 1 to 8). Note that when expressed in log form expression (6) can bee seen as analogous to a traditional regression that estimates a separate intercept for each respondent. As such, the effect of time salience (a between-subjects factor) is absorbed in the individual-specific terms in (6).

The results, presented in Table 1, provide a clarified view of the evidence for *H3*. As time passed subjects were significantly more likely to renege from long-tailed distributions when there were 12 initial queue options compared to 2($\chi^2 = 8.3$, *p<0.001*). In the case of the uniform distribution we see the same directional effect, but it is only marginally significant ($\chi^2 = 2.3$, p=0.10).

One other finding that emerged from the analysis was the unexpected finding of a significant positive effect of game number for both distributions, implying that reneging propensities increased over time (uniform: $\chi^2 = 12.9$, p<.001; long-tailed: $\chi^2 = 32.8$). What is important about this result—particularly for the case of the uniform distribution—is that it

strongly rejects the possibility that respondents may have learned to wait in a more optimal

manner as experience with the game grew—something that would have been evidenced by a

significant *decrease* in mean hazard rates over time. But rather than learning that to be patient, if

subjects learned anything it was to become more impatient as the task wore on.

Discussion, Study One

The results of the first study provide initial support for the basic hypotheses that reneging

rates would display an inverted *U*-shape over time (*H1*), and that reneging rates would be

exacerbated by making elapsed time and outside options more salient (*H3* and *H5*). In addition,

we also found support for the hypotheses that reneging rates would be too high in queues where

is optimal not to renege (*H2*), but too low early in queues where is optimal *to* renege (*H2a*).

One strong methodological note of caution must be emphasized in interpreting these

findings, however. Because each respondent made their own decision on how long to continue a

given wait (assuming that it was not yet successful), there is always the concern that the decrease

in reneging rates that we observed over longer wait times could have arisen simply due to a

survivor bias. That is, as time progressed during a wait the evidence for reneging rates was

increasingly being drawn from a sample of respondents who were generally more patient in the

task.

Arguing against this interpretation, however, was that there was evidence that the sample

was relatively homogeneous in mean reneging rates. Specifically 65% of subjects were within

10% of the mean rate of reneging, with a few reneging at a lower rate and a few at a higher rate.

Moreover, a histogram of mean reneging rates does not show a bimodal pattern that would be

congruent with distinct segments of patient and impatient respondents, and a Shapiro Wilk test of

normality shows directional (W=0.98, p=0.09) support for a hypothesis that the histogram of

responses was normal. Despite this, it is clear that a stronger test of the functional form of the hazard function would come from a task where temporal invariance in the sample was controlled by making the option to renege available only at fixed time points during a wait. Such a variation will be reported in Study 2.

Finally, a possible cause of the failure of subjects to renege in the optimal 6-18 second optimal in long-tailed distributions is that they held pessimistic beliefs about the most likely length of alternative waits—counter to the hypothesis of an optimism bias. If respondents felt that the likely wait from starting a new one would be long, they would thus have little incentive to abandon a current wait. To test for this possibility, we examined the estimates of recalled mean waits for each of the distributions subjects provided after the task as part of their debriefing. These judgments, however, tentatively rejected such an explanation for the finding. Consistent with the hypothesized optimism bias, 67% of subjects reporting an expected the mean of the long tail distribution that was lower (<15.5) than the arithmetic mean (a more rigorous investigation of beliefs about waiting times will be reported in Study 3).

Study Two

The objective of the second study was to document frequency of reneging after controlling for the amount of time the subject stayed in the wait (survivor bias) and to also collect two sets of process data: reasons for reneging from a specific wait (collected immediately on terminating a wait) and retrospective reports of the overall strategies used to make decisions over all waits (collected on completing the main task). Subjects were sixty-eight undergraduate business majors who completed the task for course credit.

Experimental Design and Procedure

The experimental task was the same as in Study One; subjects made repeated wait decisions within an overall time budget. There were, however, two differences. In Study One a "stop" button was always available to them and subjects could terminate the wait at any point in the wait. In the current study, however, the stop button was made available to subjects only after waiting a discrete interval of time. Specifically, the stop button became available after 5, 10, 15 or 20 seconds of elapsed wait and remained available for the rest of the wait. The exact order of presentation was randomized within and across individuals. If a subject exercised the option to terminate a wait he/she was then asked to indicate the reasons for termination. This was implemented by presenting subjects with a list of possible reasons for termination (see Table 2), for which they indicated the item that best reflected their primary reason for termination. Upon completion of the entire task subjects were asked to provide an open-ended description of the processes they used to decide whether to stay or renege during their waits, as well as to indicate the value of any specific waiting-time thresholds that may have used.

Analysis and Results

To examine whether we would continue to find support for the predicted *U-shape* relationship between reneging rates and waiting time after experimentally controlling for survival bias, we computed the proportion of subjects who reneged within 2 seconds of the stop button becoming available. For example, if the stop button was available after 5 seconds of wait, then renege frequency at 5 seconds was determined by looking at the number of subjects who reneged before the 7th second of wait. Similar frequencies of reneging were calculated for other points in time, and are plotted in Figure 4. As can be seen, even after controlling for self selection, we observe an inverted *U*-shape reneging rate over time The figure also reports the *p* values of pairwise *z*-tests of differences of proportions of reneging between adjacent waiting

times. For example, in the case of the uniform distribution, after 5 seconds of elapsed wait the frequency of reneging was 40% while after 10 seconds this increased to 55%--a difference greater than would be expected under standard thresholds of chance ($p=.02$).

We might add that the data from the second experiment provided similar reinforcing support for *H2, H3*, and *H5*. Specifically, as predicted by *H2*, the frequency of reneging for the uniform distribution (28%) and for the long tail distribution (35%) was significantly higher ($p<0.01$) than normative prescriptions. Likewise, the observed rate reneging (33%) for the long tail distribution between the 6th and the 18th second was significantly ($p<0.01$) less than 100%, providing support for *H2a*. Finally, as in Study One, mean reneging rates were higher when there were a larger number of queues from which to choose (38% v. 44%; $p<.05$; *H3)*, and when the elapsed time was made salient to subjects (34% v. 45% %; $p<.01$; *H3*).

In Table 2 we summarize the dominant reasons providing by subjects during the course of the task for reneging from waits for both types of distributions. The data provide support for some of the psychological drivers of reneging hypothesized by expression (3). For example, the most popular reason for decision to renege (mentioned in 32% of decisions) was that the wait time had exceeded a pre-determined threshold—consistent with the existence of a prior expected wait, t_0^*, beyond which the experienced disutility of waiting becomes sever (expression 4). Likewise, subjects also indicted being influenced by the emotional cost of the wait (mention in 16% of cases given a uniform wait distribution, 12% given a long tail) and uncertainty about its likely duration (21% uniform and 20% long tail). Finally, consistent with the predicted tendency for initial expected wait times to be marked by an optimism bias, 15% of waits were terminated simply out of a belief by subjects that they might "get lucky" by starting a new one.

We might add that the relative frequency of these reasons also varied as a function of the two main context variables in manners that might be expected. For example, when elapsed time was made salient to subjects they were more likely to mention time thresholds the prime reason for reneging, (Uniform $-p<0.00$, Long Tail-$p<0.001$), as well as uncertainty about the future length of the wait (Uniform $-p<0.005$, Long Tail-$p<0.02$). On similar lines, when there was a large number of queue options subjects were more to mention optimistic future waits (Long Tail-$p<0.0002$) as reasons for reneging.

An analysis of answer to open-ended questions provided after subjects completed the main task revealed that most (Uniform 81%, Long Tail 95%) subjects indicated having pre-set time limits or thresholds beyond which the decisions was to always renege. Of these, approximately 19% also provided numeric values for their thresholds for each type of distribution. The average of these estimates was slightly lower than their expected mean (Uniform 14.8 v 15 seconds, Long Tail 14.7 v. 15.5 seconds), which is consistent with the theorized optimism bias. Likewise, at an individual-level, the majority of subjects (80% for uniform and 75% for long tail) set thresholds lower than the theoretical mean.

Discussion, Study Two

Even after controlling for survival bias, in Study 2 we find support for the predicted *U*-shaped relationship between reneging and elapsed waiting time, as well as the conditioning effects of the salience of elapsed time and alternative queues. In addition, the data provide preliminary insights into the process that drive waits. As predicted by Figure 1, decisions to stay or bail do not seem rooted in long-term strategic computations of how repeated bailing decisions will affect total rewards, but rather short-term considerations about the perceived value of the

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current wait versus an alternative—such as the emotional costs of the wait "I've just had enough", and the likely value of an alternative "I feel luck with a new wait".

At the same time, such self-reports of reasons fall short of providing a direct support for the more detailed structural elements of the theory, such as the presumption that there is a disutility of waiting that decreases at a nonlinear rate in the course of a wait (expression (4)), and the hypothesis that prior expectations about the likely length of waits will be overly optimistic. To test these aspects we conducted a third study that elicited concurrent measures of subjects' beliefs about and attitudes toward waits as they evolved.

Study Three

Design and Procedure

Subjects were 30 undergraduates who agreed to participate for course credit. The basic experimental design remained the same as the earlier two studies: subjects made repeated wait decisions within an overall time budget, salience of outside options was varied within subjects, and availability of an external aid was varied between subjects. Unlike in the previous tasks, however, at a single point in time during each wait subjects were asked to make a forecast of how long they felt the future wait would be, and report how disappointed they felt with the wait to date. Specifically, at one randomly pre-selected point in time each wait was paused and individuals were asked to forecast the duration of the wait by checking one of three time interval segments and were asked to mention the extent to which they were disappointed with the wait by marking the response on a 5-point Likert scale. The goal of these measures to directly test two structural aspects of the hypothesized waiting process: the form of the disutility function for waiting and the conjecture that prior beliefs about the length of waits will be overly optimistic.

Analysis and Results

To test whether subjects also held overly optimistic beliefs about the likely duration of waits, in Figure 5 we plot for each time interval two proportions: the actual proportion of subjects who expected the wait to end within the time interval as judged after 2 seconds of waiting, and the normative proportion based on the expected probability of the wait terminating within the time interval, conditional on the fact that it has not terminated prior to the start of the interval. For example in the uniform distribution, after 2 seconds of wait the proportion of subjects who expected the wait to conclude within the first 10 seconds was 42%, while the normative answer was 29% should have chosen the interval.

For both the uniform and the long tail distribution we see supportive evidence for an optimism bias; i.e. a substantial proportion of subjects after two seconds of elapsed wait expected to complete early (i.e. during the first 10 seconds of the wait). Note that if the proportions were re-aggregated after removing the proportion of uncertain responses, then the optimism bias would be magnified. A large portion of consumers (20% for uniform and 13% for long tail) picked 1-10 seconds as the total time of expected wait even after waiting 14 seconds of elapsed wait, an error in estimation of elapsed time that is mitigated when a clock is available to track duration (see Figure 5).

Central to Figure 1 and expression (4) is a hypothesis that ongoing waits will induce an escalating sense of displeasure that heightens the probability of reneging. In Figure 6 we plot mean ratings of disappointment with waits that had reached varying durations for each distribution. The data support this hypothesized effect of elapsed time; satisfaction with the wait decreased monotonically over time for both distributions (global *r(disappointment, time)=0.85; p<.01*) and, consistent with the reasoning leading to Hypothesis *5,* disappointment was exacerbated by the presence of an external aid to track elapsed duration (t=2.26,. df=28,p=0.07).

Disappointment was also nominally higher given larger number of queues (Hypothesis *3*), however the effect was only marginally significant (t=1.96,. df=28, p=0.1).

Our theory also proposed that the shape of the disutility function for waiting would be nonlinear, with the marginal disutility of time being higher for waits that exceed an initial expectation (t_0^*). Although our ability to fully test this hypothesis was limited by exit bias-- we could only record disappointment when it was insufficient to trigger reneging--Figure 6 nevertheless displays some visual evidence for the hypothesized kink in disutility, particularly in the case of the long-tailed distribution, where respondents tended to renege after longer experienced waits. Specifically, superimposed on each figure is the mean total expected wait time as recorded after 2 seconds plotted in Figure 5 (i.e., the plotted interpolated mean plus 2). In both distributions linear time slopes fit to disappointment ratings are more negative after these expectations than before (*b*=-.281 before, -.465 after for the long-tailed; *b*=-.417 before, -.490 after for the uniform). Only the former of these two pairs slope differences, however, approached statistical significance (F=2,26; df=1,221 p=0.13 for the uniform; F=2.5; df=1,221; p=0.1 for the long tail).

Study Four

The objective of the final study was to explore the effect of two additional moderators on reneging decision: the level of activity that the decision maker is engaged in during a wait (*H4)* and the availability of information about the waiting time in an un-chosen queue (*H6)*. These hypotheses were tested with the same basic experimental paradigm used in studies 1-3; subjects made sequential decisions whether to stay or renege from a series of waits within a total time period of 150 seconds. Like the previous studies, subjects faced one of two types of waiting-time distributions: uniform or long-tailed. Unlike the earlier studies, however, the number of

download options was held constant at two throughout the experiment, and subjects were also informed of elapsed time during all waits.

Activity during wait was varied at two levels "active wait" or "passive wait". Subjects in "active wait" were required to press a button every one second to progress in the wait while subjects in the "passive wait" were similar to previous studies where they advanced through the wait automatically on starting a wait. In both conditions the subject had the stop button available at all times to leave the wait.

Feedback about waits in alternative queues was varied at three levels – no feedback condition, positive feedback condition and negative feedback condition. The no feedback condition was similar to previous studies where subjects received no feedback about the length of the wait in the un-chosen browser. For feedback conditions, during the course of the wait subjects were informed about the length of the alternative wait. Specifically, in the positive feedback condition subjects were told after 25 seconds of wait that the alternative wait would have ended at that point and in the negative feedback condition subjects were told after 5 seconds of wait that the alternative wait would have ended then. Hence, in the positive feedback condition the other browser took a longer than expected time to load and in the negative feedback condition it took a less than expected to load.

Feedback was varied between subjects; that is, subjects either received feedback about alternative waits or they did not. However the nature of the feedback i.e. positive or negative was presented within subject. The order of presentation was selected using a random draw. Activity within the wait was varied within block by informing subjects that they would take part in 2 games "Single click game" and the "multiple click game" each of which would last 4 rounds each. The single click game was similar to previous studies "passive" waits. In the multiple click

game subjects were required to click on a continue button every one second to advance the wait i.e. "active" waits. The exact order of presentation of the single click game or the multiple click game was randomized. Subjects were 50 undergraduate students who agreed to participate in the study as part of their regular course credit.

Analysis and Results

In Table 3 we presented the mean reneging rates for each distribution by experimental condition. First, the data support the hypothesis that active waits would display lower rates of reneging. Across all conditions the mean rate of reneging under passive waits was 33% compared to 23% under active waits (p<.01), thus supporting *H3: Activity during wait*.

Results also supported the hypothesized differential effect of seeing that the alternative wait was longer or shorter than then current. Recall that central to the work was a hypothesis that respondents would hold optimistic priors about the likely length of waits. Seeing that alternative waits were shorter than their own was thus hypothesized merely confirm these priors, thus having little effect on reneging rates. In contrast, if respondents saw that the alternative wait was much *longer* than their own, these optimistic priors for new waits (t^*) were hypothesized to be revised upward, significantly reducing rates of reneging. The data confirmed this expected pattern; when respondents saw that the alternative website took longer time—25 seconds--to download mean reneging dropped from 34% to 20% (p<.01). In contrast, when saw that the alternative website took only 5 seconds to download reneging rates were comparatively unaffected (34% v. 31%; p=.04 for the Uniform distribution, p>.1 for the long-tailed). Taken together, these offer support for *H6: Observed duration of alternative queue*.

We might add that, though not plotted here, as in the previous three studies reneging behavior over time displayed the hypothesized U-shaped function over time. That is, for both

distributions mean reneging increased to a point near the arithmetic mid-point of each wait, then decreased.

General Discussion

The purpose of this work was to explore the process that underlies consumer decisions to make decisions whether to stay or renege from sequences of queues with uncertain waiting times. Our work was motivated by observation that consumers abandon queues far more readily than would be prescribed by normative analyses. Specifically, it is easy to show mathematically that it never pays to abandon waits from symmetric stationary waiting-time distributions that one intends to ultimately complete. Yet, anecdotally violations of this principle seem routine, such as prisoners who attempt escapes just before their terms are up, or consumers who abandon phone queues that were just about to be answered.

Why might such violations occur? Central to this work was a dynamic theory of stay-or-renege decisions that posits that when consumers enter into queues its on-going value is assessed by a subjective expected utility function that discounts the expected reward offered by a wait by a convex combination of two opposing influences: the rational desire to see waits through to their completion (completion utility, $V(R)F(t_t^* - t)$ and the desire to abandon actions that are the source of displeasure or stress (waiting utility, $V(R)G(t)$). These two factors were theorized to act on the utility of a current queue in a nonlinear fashion, with completion utility accelerating upward as the amount of expected to remain in a queue diminishes. The second factor, waiting utility, was theorized to display a prospect-theory-like asymmetry in time, being concave and accelerating downward was elapsed time exceeded a critical expectation. As time evolved in a queue consumers were predicted to be most vulnerable to reneging near the mid-point of a wait, at time when the experienced displeasure of waiting would be high but and the prospect of completion would remain distant.

The extent to which this pattern of reneging would arise in a given setting, however, was also theorized to be conditioned by a number of contextual moderators. For example, a central element of the theory is that as waits evolve, the attractiveness of the current wait is compared to an idealized vision of the most likely *best* wait that could have been obtained by choosing other queues. As such, rates of reneging were hypothesized to be increasing in the number of original options—a factor that would be normatively irrelevant to deciding whether one should renege (since all options would have had the same priors). We also hypothesized, however, that this same effect would be mitigated if one were given direct information showing that one would not have had a shorter wait had one of the original alternative queues been chosen. Likewise, we hypothesized that task variables that made the passage of time either more salient (posting a clock) or less salient (engaging in physical activity) would affect reneging rates by either drawing attention to the displeasure of waiting or away from it in the course of waiting.

Supportive evidence for the proposed theoretical process was provided by data from four laboratory studies. These data, for example provided repeated evidence of the hypothesized inverted *U*-shape evolution of reneging rates over time, even after controlling for survivor bias, and direct support for the hypothesized optimism bias in expected waits—a bias that persisted as waits progressed. Direct reports provided by respondents about why they made the decisions they did were also consistent with the proposed mechanism. Supporting the idea that queue assessments are made by reference to benchmark expected waits, for example, the most frequently-mentioned reason for reneging was that a given wait had exceeded a pre-set threshold—despite the fact that such thresholds almost never had a rational basis in the task.

Limitations

The proposed theory of reneging was designed to represent behavior with a specific class of waiting-time problems where position in a queue was unobserved, abandonment required starting a new wait from scratch, and all queues had identical waiting-time distributions and ending rewards. While there are reasons to believe that the findings would generalize to a broader range of task settings, caution must be exercised in making such extensions.

To illustrate, note that the data reported here were gathered from a task where waiting and expectations were quite short, mimicking the management of web-page downloads. Under the current theory, the absolute scale of waits is assumed to be irrelevant to how stay or renege decisions are made. That is, we would expect to see the same biases had the currently problem been cast in a setting where waits are measured in hours (or days) rather than seconds. Indeed, anecdotal evidence would seem to support such an extension; most of us, for example, have succumbed to the error of abandoning our normal route to work when traffic seems backed up only to later conclude that it would have been shorter just to persist in the wait, mimicking the core bias observed among subjects in the current task. On the other hand, such an extension may not hold when waits are taken to extremes, such as days or weeks. One prediction for such cases that could be accommodated by the current theory is that as waits become extreme it begins to diminish the perceived salience of alternative queues ---causing the locus of the bias to shift to one of *under*-reneging

Likewise, it is unclear how the current findings would generalize to settings where waits are visible, or where one can infer the length of a future wait from environmental variables (such as whether one sees a traffic accident ahead on a road). Perhaps the most natural prediction is that such information would temper excessive optimism about the value of alternative waits, hence decrease the rate of reneging. Yet, this same clarity of knowing that the wait will be

longer than expected might also heighten its associated angst, causing an increase in reneging—an effect that would be akin to the current finding of increased reneging when elapsed time is made salient. It might be the case that prison escapes near the end of terms because, ironically, the very prospect of an impending release increases the salience—hence the psychic pain—of the time that remains.

Finally, the effect of imposing temporal correlations in wait times is also unclear, as it would depend on the nature of those correlations and the ability of decision makers to perceive them. For example, if decision makers were led to believe that waits were negatively correlated—a long wait now likely means a shorter wait later—we might see the current reneging biases exacerbated relative to normative levels, as decision makers may come to overly rely on long current waits as assurances that the next one will be short. In contrast, beliefs that waits are positively correlated could serve to dampen biases elative to normative levels by dissuading attention to foregone alternatives.

Directions for future research

This work adds to the growing field of research examining how individuals process time information while solving dynamic decision problems. Some of the ideas uncovered here are familiar, and serve to broaden our understanding of the scope of their application. For example, the current work reinforces the idea that waiting in queues can be a significant source of stress for consumers, and that it can lead to suboptimal behaviors—in this case, reneging from queues in which consumers would have better of staying. Likewise, the data support the widely-held intuitive idea that impatience and stress in queues can be reduced by increasing activity during the wait and focusing attention away from alternative wait options.

At the same time, the current work also offers a range of findings that offer new theoretical insights into time cognition. Perhaps the most important is that it offers the first detailed psychological portrait of the process that leads to decisions to renege in the course of a wait. Decision makers are shown to enter waits with overly optimistic expectations of waiting times, and disconfirmation of this process triggers a cascade of cognitions that lure abandonment, including heightened feelings of disappointment, and stress. Only when a decision maker approaches the plausible end of a wait—when senses of disappointment are overcome by the desire to avoid abandoning the time that has been invested in a wait--do these pressures begin to ease, resulting in an inverse-U-shape relationship between the hazard of reneging and waiting.

As suggested above however, it is important to emphasize that the data here were gathered within a restricted task setting, and an important goal of future work is to expand its scope both empirically and theoretically. For example, one next step would be to explore the degree to which the findings reported here generalize to the kind of broader task settings described above, such as cases where progress in queues is observable and waits in successive queues are not independent. Perhaps even more critical is the task of expanding the inquiry to a broader range of substantive problems where queue management is an issue—such as R&D departments at firms who must decide whether to continue investing in the development of projects. What makes problems of this sort fundamentally different from the current is not only can queues be rejoined in progress once started, but also the size of the reward is uncertain at the start of the wait, and is revealed only gradually as a wait is incurred.

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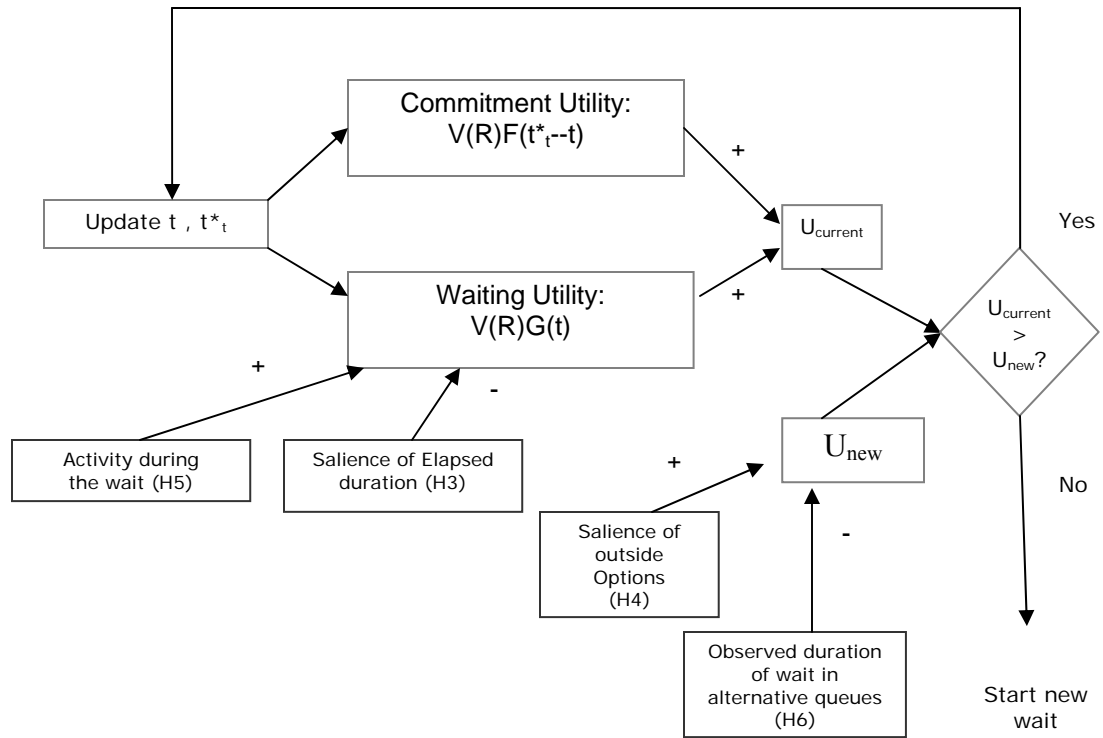
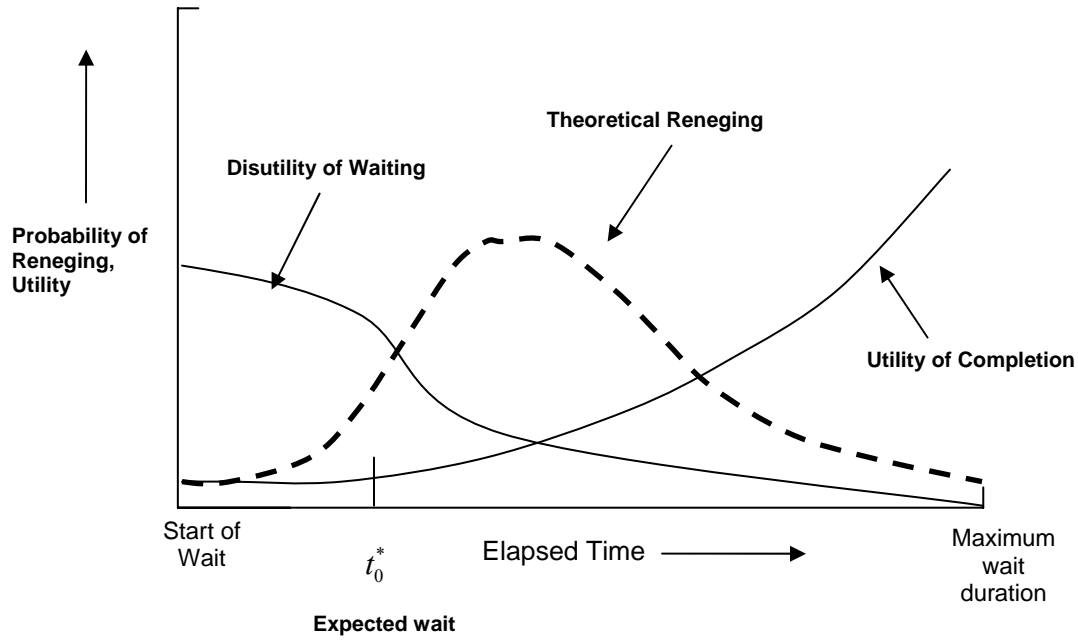Figure 1: The hypothesized process of sequential stay-or-bail decisions

Figure 2: Theoretical rate of reneging over time. The figure illustrates the case of a consumer who equally weighs the two sources of utility, has an initial optimistic prior about the length of the wait ($t_0^* < \bar{t}$) and rationally revises expectations of about its length in light of elapsed time (e.g., if the distribution is uniform, $t_t^* = \overline{(t_{max} - t)}$).
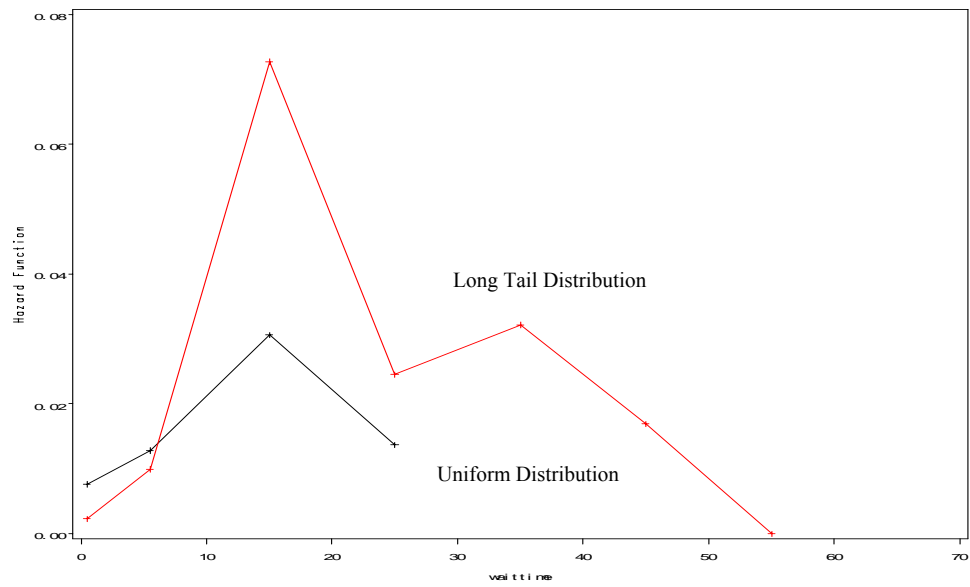
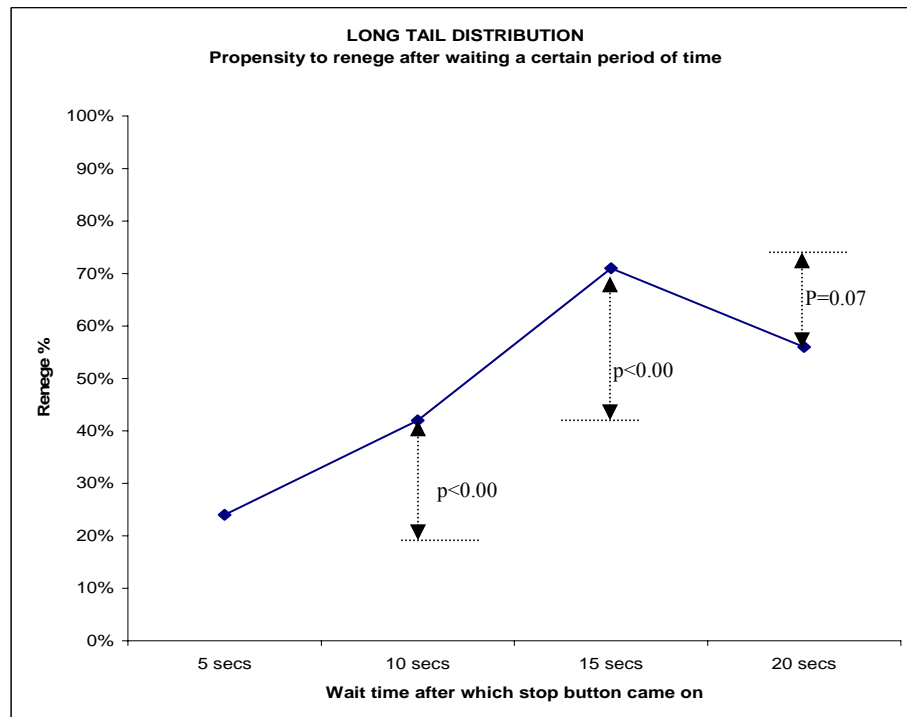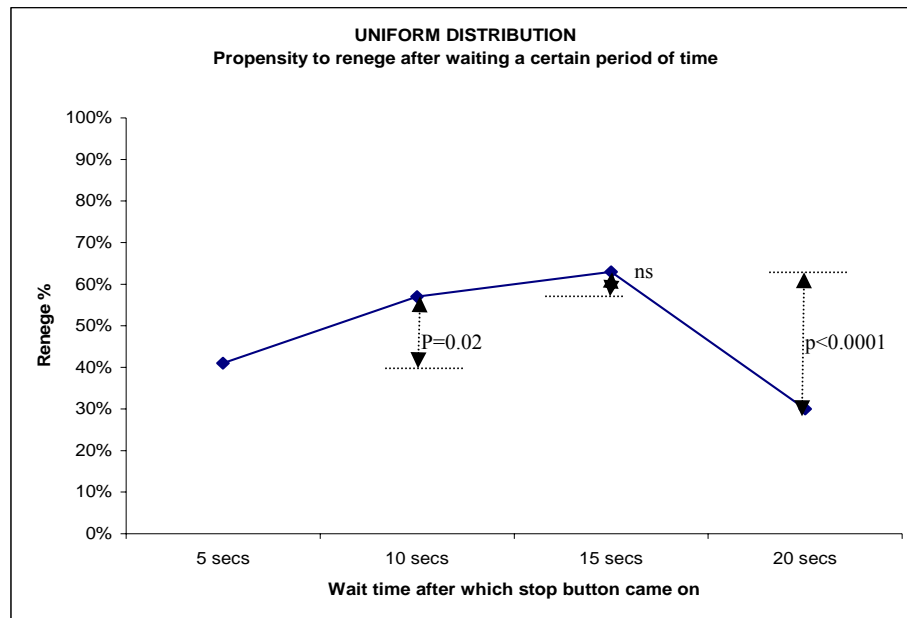Figure 3: Empirical Hazard functions over time by waiting-time distribution, Study 1

UNIFORM DISTRIBUTION
Propensity to renege after waiting a certain period of time

Renege %

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

ns

P=0.02

p<0.0001

5 secs   10 secs   15 secs   20 secs

Wait time after which stop button came on

LONG TAIL DISTRIBUTION
Propensity to renege after waiting a certain period of time

Renege %

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

P=0.07

p<0.00

p<0.00

5 secs   10 secs   15 secs   20 secs

Wait time after which stop button came on

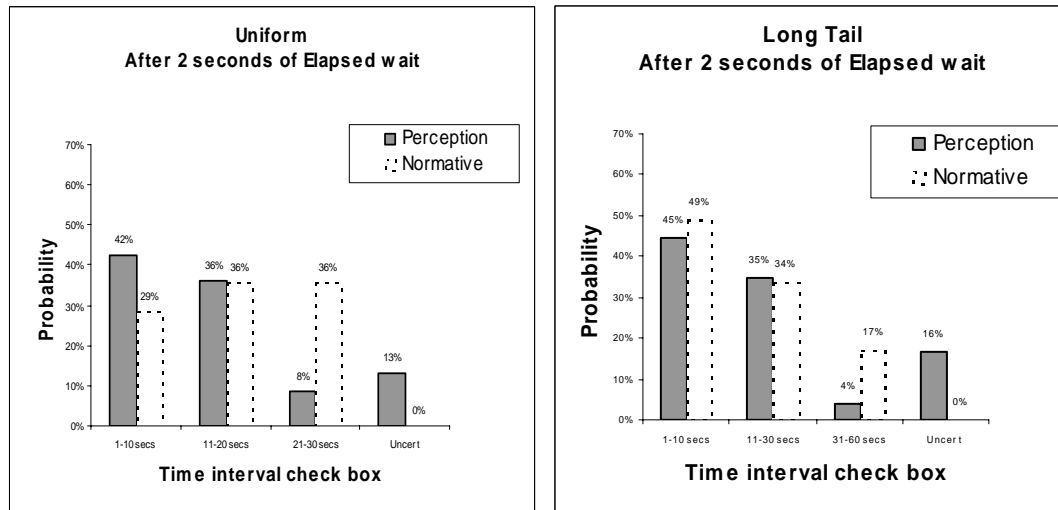Figure 4: Observed rates of reneging by distribution and forced waiting time, Experiment 2

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Figure 5: Perceived v. normative future waiting time distributions, Study 3.
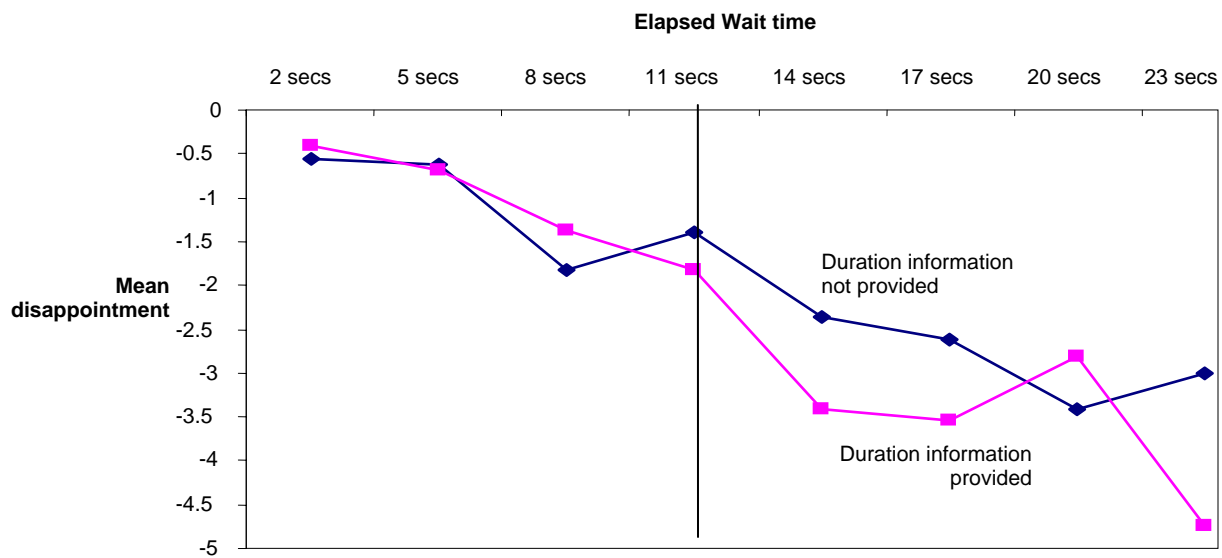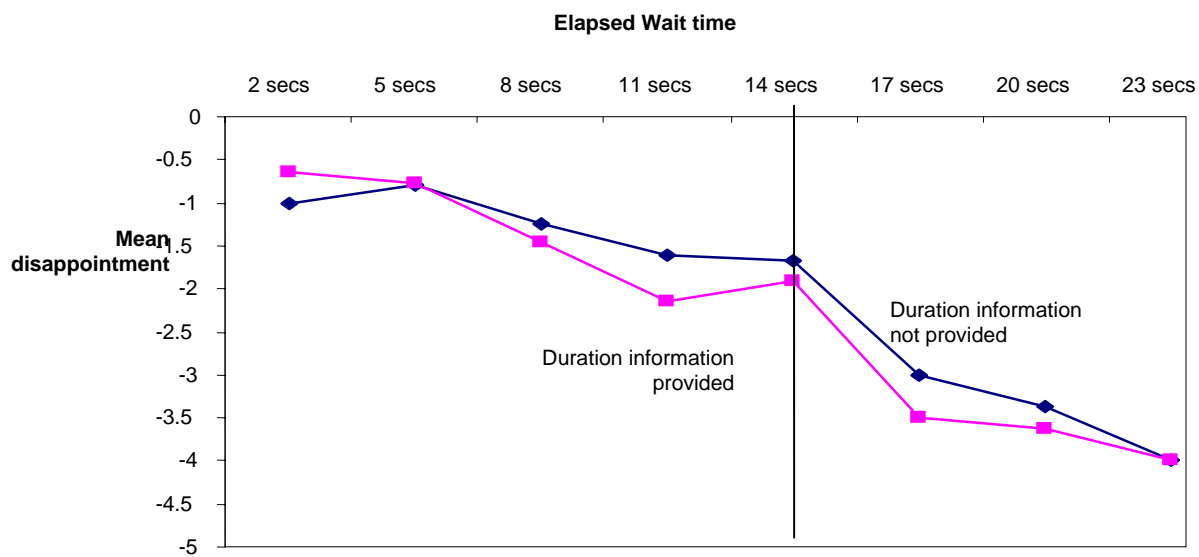
Figure 6a Uniform Distribution

6b: Long Tail Distribution.

Figure 6: Rated disappointment with wait by elapsed wait time and availability of duration information by Distribution, Study 3. The vertical bars plots the mean total expected wait times measured after 2 seconds of waiting implied by Figure 5 (11.5 seconds uniform, 13.5 seconds long-tailed).

Table 1

Cox Proportion Hazard Model of Reneging Decisions, Study 1

Uniform distribution

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	44.1692	3	<.0001

Analysis of Maximum Likelihood Estimates

Variable	DF	Parameter Estimate	Standard Error	ChiSq	Pr>ChiSq	Hazard Ratio
Salience of outside options	1	0.153	0.100	2.3	0.10	1.166
Time left	1	0.005	0.001	27.6	<.001	1.006
Game number	1	0.081	0.023	12.2	<.001	1.085

Long Tail distribution

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	42.8170	3	<.0001

Analysis of Maximum Likelihood Estimates

Variable	DF	Parameter Estimate	Standard Error	ChiSq	Pr>ChiSq	Hazard Ratio
Salience of outside options	1	0.252	0.087	8.3	0.003	1.287
Time left	1	0.002	0.001	6.8	<0.001	1.002
Game number	1	0.125	0.021	32.8	<.001	1.134

Table 2: Reasons for reneging from a wait for both types of distributions, Study 2

	Type of Distribution	
	Uniform	Long Tail
N=	268	295
Couldn't take it any longer	16%	12%
I'm not sure how much more time it will take	21%	20%
I'm sure that it will take a lot more time	7%	8%
I think I will be lucky if I try again	15%	16%
It crossed threshold I had set	30%	33%
Other reason	3%	6%
No reason	16%	10%

Table 3: Renege proportion by activity within the wait and feedback about length of alternative wait, Study 4

3a. Uniform Distribution)

Dependant Variable -   Renege %

	UNIFORM DISTRIBUTION		
	No Feedback

secs) | -ve feedback
(alt wait = 5 secs) | +ve feedback
(alt wait = 25 |
| Passive wait | 45%

P<0.00 | 42%

P<0.00 | 30%

P<0.00 |
| Active wait | 35% | 26% | 15% |
| | P=0.04 | P<0.00 | |

Table 3b: Long-Tail Distribution

Dependant Variable -   Renege %

	LONG TAIL DISTRIBUTION		
	No Feedback

secs) | -ve feedback
(alt wait = 5 secs) | +ve feedback
(alt wait = 25 |
| Passive wait | 32%

P=0.05 | 29%

P<0.05 | 20%

P<0.00 |
| Active wait | 24% | 24% | 14% |
| | P<0.00 | | |