Present-Bias and Salience in Discounting Across Short Durations: a Proposed Experimental Approach *

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Abstract

This paper proposes two modifications to the experimental design of Benhabib et al (2010), which elucidates the presence of a fixed-cost present bias for intertemporal choice across large durations. The two changes are the usage of shorter delays, for which the salience between the present and the future is not as strong, and the possibility of framing the waiting time so as to restore or diminish the aforementioned salience. We posit that the reduced salience due to shorter delays will in fact reduce present bias; while removing information about the duration or enhancing the feeling that time is passing will restore some of this present bias. We lean upon Benhabib et al. (2010)'s non-linear specification to extract parameter values for this present bias, which then serves as a basis of comparison for our model. Despite evident theoretical, experimental and econometric issues that need addressing, this paper hopes to serve as a foundation for further empirical work on time preferences across short delays. Indeed, it might also be useful in informing policy on the role of framing salience on intertemporal choices, and lead previous research based on longer delays to pursue a modelisation with a more realistic, shorter delay.

KEYWORDS: salience, framing, present bias, discounting

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1 Introduction

One of the most well-known contributions of behavioural and experimental economics is in the reconciliation of observed ”irrational” behavioural regularities in time preferences that are incompatible with standard economic reasoning. After several decades of finetuning the experimental and econometric approach, the work of psychologists and behavioural economists in this field has come to a general consensus that these deviations from standard ”rational” behaviour are systematically due to agents having a hyperbolic discount curve with a fixed cost of present bias, and numerous experiments have been conducted to that effect. Indeed, discounting has been shown to decline in both time - known as the present bias - and in the amount - known as the magnitude effect.

However, a large majority of this empirical literature that deals with the present-bias uses time periods of an order of magnitudes of days, weeks and months. This representation of the future implies a significant temporal distance between the present $t = 0$ and the future $t > 0$, but is subject thus to the critique that experimental subjects are likely to perceive payoffs that are (at least) several days away with a certain amount of uncertainty, which may obfuscate the true time preference factor at hand. In addition, while the future might indeed be salient for longer orders of magnitude, there is no guarantee that the results the empirical literature has found are valid at shorter temporal orders of magnitude, such as hours, minutes or indeed seconds.

At these shorter durations, there might be cause to wonder if the sharp distinction between present and future we usually obtain in experiments is no longer as salient, and that under this lack of salience, there might not be a sufficiently clear relative ’present’ to be biased towards. **Do we expect then to observe the usual present-bias when durations used in the experiments are much shorter?** In addition to providing insight into time preferences on shorter durations, an experiment run on durations of shorter temporal orders of magnitude are less subject to the possible distortionary effects of uncertainty.

If indeed the present-bias is shown to be diminished under durations of shorter temporal orders of magnitude, **we can ask whether this is the result of a lack of salience between the present and the future**. As such, an experiment that restores salience through the provision of additional temporal cues - so as to, for instance, reinforce the feeling of the passage of time - might be expected to partially restore to a stronger present-bias than in the absence of salience. If the difference is statistically significant, then we might able to draw a conclusion about the role of salience in the perception of the future. Indeed, this will provide insight into an age-old question in behavioural economics and economic psychology: when does the future start?

This paper will propose a simple variation to an experimental protocol inspired by Benhabib. et al. (2010) [8] in testing for time preferences by incorporating the novel elements of (i) a four-treatment waiting time prior to the elucidation of preferences, and (ii) the use of shorter durations that range from 2 minutes to 60 minutes. In particular, the four-treatment waiting time will allow us to frame for different levels of salience that would allow us to compare the results we obtain under shorter duration with those found in traditional literature, and compare the results under shorter duration under different levels of salience. We work under the hypotheses that the shorter duration will suppress the present-bias, while introducing or removing different types of salience from the individual's temporal perception can restore some of this present-bias.

These findings would allow us to better inform behavioural policy, in particular in cases where durations do not expect to last beyond a day. In particular, a number of strategic environments in which time preferences come in - such as risk management, health economics, commitment and procrastination - are equally likely to occur in the long-durational time frame traditionally cited in time preference research and in the short-durational time frame we propose above. It is hoped that our results about salience will also further inform policy in terms of how the quantity, quality and framing of information might affect desired outcomes.

This paper is divided into the following sections: in part 2, an extensive literature review will be conducted, looking at both theoretical and empirical approaches to time preferences, and also psychological research into waiting time and its effect of human behaviour. In part 3, the proposed experimental protocol will be detailed; while in part 4, the hypotheses and proposed empirical treatment of the data obtained in the experiment will be briefly discussed. In part 5, we look at if and how this approach addresses or overcomes previous experimental issues, and then elaborate on some of the new shortcomings this novel experimental approach is subject to. In part 6, we provide a summary conclusion of our paper. All experimental figures and materials are found in the appendix that follows.

2 Literature Review

The following section is split into two main sections: the first looks at the vast theoretical and empirical literature in behavioural economics related to time preferences, in particular at the key model axiomisations and the role of **present-bias** in these models. We will focus on how Benhabib et al. (2010) [8] used a then ground-breaking experimental protocol to extract data on the time preferences, and then used various econometric tools to extract information about the hyperbolicity, or curvature, of the discount function of individuals and the existence and form of a present bias. In the second section, we focus on waiting time, and previous psychological and neuro-economic research that shows how time perception (independent of whether this time is spent waiting or not) is subject to framing effects.

2.1 Discounting

Time preferences or delay discounting have been a central branch of research in behavioural economics, with the explicit aim of understanding **discounting**: why individuals preferred consuming a bundle of goods now (immediate consumption) to consuming an identical bundle of goods in the future (delay consumption), and how this discounting changed with the remoteness of the future. In addition, a key aspect of this research focused on **present bias or preference reversal**: why people are observed to prefer larger, later bundles of goods to smaller, sooner bundles when both of these events occur with a sufficiently large delay, and why this preferences reverse as the delay gets smaller. Much of the early economic research done here has sought to provide formal models that depend mostly on highly abstract and stylised axiomisations at the expense of empirical traction; it is only recently that experimental work, primarily done by psychologists, has become a tool to support these axiomisations [21]. The major models of discounting in the literature thus follow a logical chronology: the purely formal exponential, the empirically-inspired hyperbolic, and the hybrid quasi-hyperbolic models are the three most important ones. Each model will be explained in this section, but it is important, however, to highlight the extent to which the research done in the late 1990s and 2000 within a number of independent and interdependent projects run by economists and psychologists, and through the combined influence of economics formalisms and psychological empirical work has led to reinforcing the hyperbolic model as the canonical discounting model of contemporary behavioural economics. The primacy of the hyperbolic model, however, remains contested till today.

2.1.1 Exponential Discounting Model

Initially postulated by Samuelson (1937) [46], and refined by Koopmans (1960) [28], the exponential discounting model was the first attempt at modelising intertemporal choice in a tractable utility maximisation context. The premise lies in that an economic agent maximises the sum of the present and all future utilities over consumption, where the future utilities are discounted by their distance in time from the present. As such, for a person with a **certain** consumption profile $(c_t, \cdots, c_T)$ that runs from period t to period T, we have the following additive utility representation in a **discrete** environment:

$$U^t(c_t, \cdots, c_T) = \sum_{k=0}^{T-t} \frac{u(c_{t+k})}{(1+\rho)^k} \tag{1}$$

where $\rho > 0$ is defined as a person's **discount rate**, where the restriction on positive values represents the discount factor. Rearranging a single $k + 1^{\text{st}}$ term of the sum as a future value and comparing it to the present value at $k = 0$, we have that

$$\rho = \left(\frac{u(c_{t+k})}{u(c_t)} \right)^{\frac{1}{k}} - 1 \tag{2}$$

For a future value, this generates a specific ρ, defined as the growth rate by which to translate present values into future values. As such, each decision maker can be said to have a threshold $\tilde{\rho}$, above which he would accept the future value: this is to say, for a sufficiently large ρ such that the future value brings a sufficiently large return with respect to the present value, he will accept to wait for the future value (Doyle, 2013) [15]. In the same logic, $\frac{1}{1+\rho}$ is the **discount factor** and the $D(t) = (\frac{1}{1+\rho})^t$ is the **discount function**. A discount function $D(t)$ is such that a subject is indifferent between the choices (c, t) and $(c \cdot D(t), 0)$; for our purposes, we assume the discount function only depends on time here. In this sense, a person with an exponential discounter would choose the larger of the present value or the future value multiplied by the this discount factor raised to the power of the length of the delay. The significance of this first manifestation of ρ should not be understated, since it became the unitary cornerstone of time preferences, as it allowed a direct quantitative measure of when the preference for immediate over delayed gratification occurs (Grüne-Yanoff, 2015) [21].

In the continuous environment, we divide each period into n intervals that we let tend to infinity, such that

$$\lim_{n \Rightarrow \infty} \left(1 + \frac{\rho}{n}\right)^{nt} = e^{\rho t}$$

and so

$$\lim_{n \Rightarrow \infty} D(t) = e^{-\rho t} \tag{3}$$

which is the canonical continuous form of the exponential discounting function. This translates into a continuous time analogue for equation (1):

$$U^t(c_t, \cdots, c_T) = \int_{k=0}^{T} e^{-\rho t} u(c_t) dt \tag{4}$$

In particular, a number of axiomisations are central to the model, many of which were postulated by Koopman (1960) [28] and Lancaster (1963) [31]. These are as follows:

1. The utility function is **concave**, which implies diminishing marginal utility, which favours future consumption, and the discount rate ρ is $positive$, which implies impatience, hence favouring present consumption. This allows for there to be a tradeoff between the current and future consumption.

2. The discounting is a **stable** unitary factor that applies equally to all consumption types and at all times.

3. The discounting is **constant** or perspective-independent, i.e. "the [preference] results are unchanged even if the individual always discounts from the existing point of time rather than from the beginning of the period." (Samuelson, 1937) [46]. An extension here would be that the discount rate is **independent of time**. A serious consequence of this is that it does not account for the temporal inconsistencies observed in individual behaviour, as we see below.

4. The utility function in an exponential discounting model is **separable**, i.e. consumption in a given period has no incidence on the preferences and choices over consumption bundles in subsequent periods.

5. The utility function in the model is also **stationary**, i.e. preferences fixed between a first bundle in one period and a second bundle in another period, then these preferences are maintained between the two bundles across two periods of the same temporal distance.

One major issue with the exponential discounting model is that it is unable to account for time inconsistencies. Indeed, the only plan that optimally ensures time consistency is the exponential discount function. As long as the lifetime consumption profile is feasible under an initial endowment ω, a decision maker maximises, with respect to the consumption in each period at period 0, and obtains an optimal consumption profile C_0. Then, this consumption profile is time consistent, if at period τ, reoptimisation at this period obtains C_τ, we have that $C_0 = C_\tau$. The implication of this is that the percentage marginal change in the discount function at both periods are the same, since the optimal solution is such that we value the future at this new period τ in the same way as at the previous period $t = 0$, i.e.

$$\frac{D_t(t-0)}{D(t-0)} = \frac{D_t(t-\tau)}{D(t-\tau)}, 0 \leq \tau \leq t \leq T \tag{5}$$

If this is an optimality condition for time consistency, we have that for all $t = k$, the value of $\frac{D_t(t-k)}{D(t-k)}$ is a constant, which is that

$$\frac{d \ln D(t)}{dt} = \text{constant} \tag{6}$$

This is only true when $D(t) = e^{-\rho t}$, which is the case of the exponential discount function. This implies that only the exponential discounting model can provide time consistency.

2.1.2 Hyperbolic Discounting Model and the Present Bias

In sharp juxtaposition to the exponential discounting model, we have the hyperbolic discounting model in which time inconsistency is possible. One particular reason for which this time inconsistency was not a feature of the exponential discounting model lies in how Samuelson (1937) [46]'s model does not closely examine the shape or slope of the discount function, since he has assumed it as a constant through time. As such, there was no room for there to be a change in the slope of the function in the model, although empirical research in psychology has been shown to happen in preference reversals and time inconsistencies (Grüne-Yanoff, 2015) [21]. These are behavioural patterns in which agents reverse preferences from preferring large consumption bundles later in the future over small bundles sooner in the future, when the consumption point approaches in time. Mathematically, this is represented by:

$$(c, t) \succsim (d, t') \text{ and } (d, t' + \tau) \succsim (c, t + \tau);\ \tau > 0, t' > t; d > c \tag{7}$$

where c, d are elements of the choice set and t, τ, t' are possible delays. Evidently, applying the exponential utility model and converting preferences into relations over utilities generates two inequalities that cannot hold simultaneously.

Building on the goal-gradient hypothesis in psychology, in which the tendency to 'approach a goal increases with (spatial or temporal) proximity to the goal (Grüne-Yanoff, 2015) [21], the work of the psychologists Mischel and Metzner (1962) [41], in which they showed that 'preferences for delayed larger rewards are negatively related to the length of the delay interval', and the matching law of Herrnstein (1970) [23], in which animals are shown to distribute choices over alternatives dependent on how strong reinforcers of these alternatives present themselves (such as through delayed reinforcement), behavioural economists codified a discounting function consistent with the above behaviours in the form of hyperbolic discounting. Again, not unlike the form Samuelson had proposed for the exponential discount model, for a person with a **certain** consumption profile $(c_t, \cdots, c_T)$ that runs from period t to period T, we have the following additive utility representation for hyperbolic discounting proposed by Ainslie (1975) [1]:

$$U^t(c_t, \cdots, c_T) = \sum_{k=0}^{T-t} \frac{u(c_{t+k})}{1+k} \tag{8}$$

It can then be shown that the hyperbolic discount function $D(t) = \frac{1}{1+kt}$, where t is the time delay between the current period $t = 0$ and a future period $t = \tau > 0$, and k is a positive parameter. The corresponding discount rate ρ is given by

$$\rho(t) = \frac{k}{1+kt} \tag{9}$$

This implies that discount rates decline in time, and that the longer the delay before a reward, the lower is the discount rate, and hence the more patient is the decision-maker. Consequently, we also have that average impatience is strongest when the delays are short, as compared to longer delays, such that in the course of time towards the realisation of the reward, rising impatience can change the order of preferences.

In particular, Ainslie (1975 [1], 1981 [2]) uses his hyperbolic formulation to show how temporal inconsistency may come about. In Figure X, for separate curves for the reward effectiveness - analogous to utility - of the larger, later reward (curve 1) and the smaller, sooner reward (curve 2), it is clear that at the beginning (i.e at $t = 0$), we observe the curvatures of two hyperbolic functions are such that the larger, later reward is more effective (analogously: brings more utility) than the smaller, sooner reward. However, as the realisation of the smaller, sooner reward nears, the curves cross, and this smaller, sooner reward is more effective than the larger, later reward for some duration before realisation and will thus be chosen, leading to an impulsive preference reversal. This switch in favour of the smaller reward close to realisation is often called the **present bias**, and the hyperbolic discounting model provides an excellent theoretical basis for this empirical observation. The hyperbolicity of the curve also thus lends itself to direct experiments, a fact that behavioural economists exploit today. (Ainslie, 1975) [1].

In particular, we might ask ourselves as what point these two curves are expected to cross, and whether this happens in all cases. This crossing approach exploited in empirical experiments today is often associated with time durations of an order of magnitude significantly large enough for this crossing to occur. Whether or not long durations are a prerequisite to see crossing aside - which is in itself an interesting question, one particular implication of this that we might then exploit is that when the reward realisation point is very close to $t = 0$, we might not see this crossing of the reward effectiveness curves, and hence we might not perceive a preference reversal indicative of a present-bias. This is the central focus of our proposed experiment.

Further inspired by Ainslie's [1] hyperbolic formulation, a wave of empirical work followed in an attempt to parametrise the shape of the human discounting function. This took the form of not only experiments that systematically tried to show the hyperbolicity of the curve, but it also took the form of experiments that tried to clearly demonstrate the non-validity of the full exponential

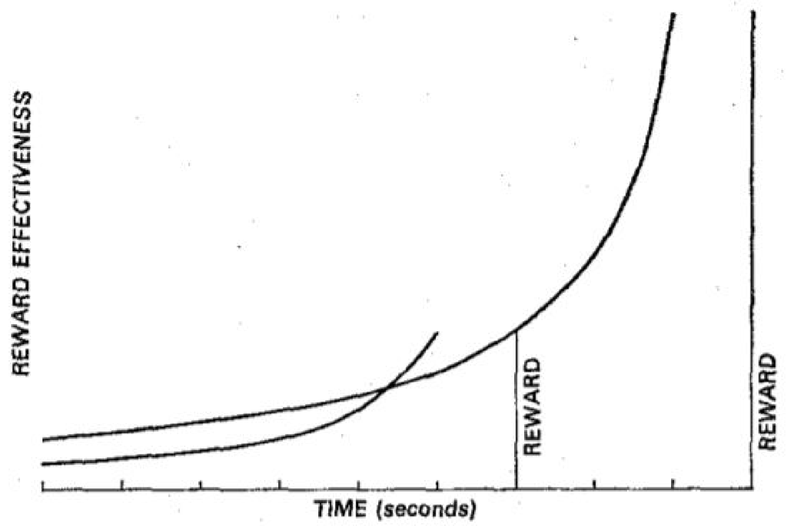

Figure 1: Source: Ainslie (1975) [1]

discounting model. In particular, a seminal work by Thaler (1981) [50] showed that in an experiment involving money-time tradeoffs between 15 dollars now and an subject-defined amount in the future, the annual discount rate fell from 345 percent for a delay of one month to 120 percent for a delay of a year and to 19 percent for a delay of 10 years: a pattern that is evidently not exponential. These values are still taken as seminal benchmark values to which much of subsequent literature compares. In that sense, the debate has more or less settled on a consensus that the hyperbolic discounting is a more accurate representation of the empirical evidence: the purpose of our experiment will then also be to corroborate this finding.

Other experiments followed, initially using hypothetical scenarios. This was proven to be a methodological minefield, in particular because hypothetical payoffs often do not elicit truthful choices and hence reveal faulty preferences. Attempts to switch to real monetary incentives for inter-temporal choice over many years were mired in other problems: there was no way for experimenters to untangle the future payoff from the uncertainty that is associated with the future. This leads to two issues: firstly, that this leads to inaccurate measurement of the discount rate, since we are unsure whether the falling valuation in the future is due to the discounting (fall in valuation) or due to the overwhelming uncertainty associated to events that months, if not years, away (agents are hedging against the unknown), and also because there is also no way to guarantee recipients will believe that they will receive the future payoff they are promised. At this juncture, we briefly mention that this confounding effect of uncertainty is significantly reduced when durations that we propose are in the order of magnitude of hours, and this might in fact enhance the accuracy of the measurement, conditional on there being no discontinuity between short and long delays.

2.1.3 Quasi-Hyperbolic Discounting Model

One of the key empirical developments that followed was the quasi-hyperbolic discounting model proposed by Phelps-Pollak (1968) [43], Loewenstein-Prelec (1992) [34] and Laibson (1997) [30], which was the product of a concerted attempt at finding a tractable model in which a continuous and separable utility function for present and future bundles are hyperbolic in curvature at short durations and exponential in longer durations, a phenomenon observed empirically (Doyle, 2013) [15]. This is best illustrated analytically: again for a person with a **certain** consumption profile $(c_t, \cdots, c_T)$ that runs from period t to period T, we have the following additive utility representation for quasi-hyperbolic discounting:

$$U^t(c_t, \cdots, c_T) = u(c_t) + \beta \sum_{k=1}^{T-t} \delta^k u(c_{t+k}) \tag{10}$$

where since β and δ, the discount factor, are parameters between 0 and 1, the fact that the first period is not subject to a discount factor generates a first decline (as in the hyperbolic case), followed by a gentler decline (as in the exponential case). A simple transformation isolates β and δ, such that the lifetime total utility is divided into a term in β, that puts extra weight on immediate rewards, and a term in δ that exhibits standard exponential discounting:

$$U^t(c_t, \cdots, c_T) = \left(\frac{1}{\beta} - 1\right) u(c_t) + \sum_{k=1}^{T-t} \delta^k u(c_{t+k}) \tag{11}$$

This implies that utility is discounted differently in the first period and in all subsequent periods, which is an intuitive way of establishing the present bias for current consumption. β thus acts as an additional motor of present bias in this model. Using this, we can show that the effective discount factor between period 0 and 1 is

$$\beta\delta = \frac{1}{1 + \rho_0} \tag{12}$$

such that the discount rate between period 0 and 1 is given by

$$\rho_0 = \frac{1 - \beta\delta}{\beta\delta}, \tag{13}$$

which is in contrast to the discount factor between any other period $\tau > 0$ and the next period $\tau + 1$, given by

$$\delta = \frac{1}{1 + \rho_\tau} \tag{14}$$

such that the discount rate between τ and $tau + 1$, for $\tau > 0$ is given by

$$\rho_\tau = \frac{1 - \delta}{\delta}. \tag{15}$$

It is thus clear, that whereas in the exponential case, the fact that the discount applies to both the smaller, sooner and the larger, later consumption bundles when they are both in the future $(t \neq 0)$ means that the discounting has no effect, when the sooner bundle enters the present $t = 0$

period, this discount only applies to the larger, later consumption bundle, hence possibly causing a preference reversal for a sufficiently small discount. It also follows that the discount rate between the other periods is lower than the discount rate between periods 0 and 1, and so the impatience is much higher at the initial period than in any subsequent period. We thus obtain the following discount function:

$$D(t) = \begin{cases} 1, & \text{if } t = 0 \\ \beta e^{-\rho t}, & \text{if } t > 0 \end{cases} \tag{16}$$

It is then clear that as the delay increases (for $\tau > 1$), the discount function gets smaller and thus the the cost of the delay on the valuation of the future consumption gets larger and larger. This is thus the variable cost dimension of the quasi-hyperbolic model.

The quasi-hyperbolic model has been widely adopted in empirical and theoretical work for this attractive property that it intuitively models this present-bias preference change. In addition, the single difference in the initial period between this quasi-hyperbolic model and the exponential discounting model allows for the testing of β in empirical studies, and provides a convenient way of pinning this present-bias down. This dominance, reflected in an influx of work on pre-commitment, behavioural game theory, etc., has anchored present-bias, and how it can be theoretically obtained and empirically verified, at the center of most empirical models (Grüne-Yanoff, 2015) [21], at the expense of other models that attempt to evaluate the actual intertemporal evaluations of individuals. However, quasi-hyperbolic models are not without shortcomings: there is only a shaky consensus on the empirical values for β (between 0.5 and 0.6) and for δ, in particular because force-fitting a quasi-hyperbolic model to a variety of empirical modelisations in time preference over health, social services and labor market outcomes tends to lead to a lot of noise from the inherent differences in the type of outcomes and the associated uncertainties that might distort the perception of the choice set and the delays.

2.1.4 Benhabib et al. (2010)'s Fixed Cost Discounting Model

Benhabib et al. (2010)'s [8] model is constructed to elucidate experimental data on preference reversals in money-time pairs and to econometrically extract the hyperbolicity of the discount function and in particular, to examine the nature of the present bias. We focus on their model because it combines an experimental dimension that is easily reproducible with an econometric specification that lends tractability to the data we obtain. Not only do we directly measure for this present bias with the data, with this specification, we are able to generate for different treatment groups comparable parameters for the present bias, hence allowing us to run specific econometric tests to check for whether present bias is affected by the salience. This model thus provides a firm basis on which we are able to test our hypotheses.

The authors propose a fixed-cost present bias, where the present bias enters additively to the model in the form of an absolute cost, as opposed to variable-cost present bias that we observe in quasi-hyperbolic models, which works multiplicatively on the value of the future consumption and hence acts as shown in the previous section, as a percentage decrement. (Doyle, 2013) [15]

Implementation. The experimental protocol is simple in that it involves two barrages of 30 questions, one framed to the present and one framed towards the future. In each barrage of questions, time-delay questions were asked over a set of money-time pairs of the general form $(x, 0)$ and (y, t). The framing is as follows:

- **Present framing, [*Q-present*].** Subjects are asked the amount of money, denoted x they are willing to accept in period $t = 0$ that would make them indifferent to y dollars paid at a delay of t. This is repeated for $y \in \{10, 20, 30, 50, 100\}$ and for $t \in \{$3 days, 1 week, 2 weeks, 1 month, 3 months and, months$\}$.

- **Future framing, [*Q-future*].** Subjects are asked the amount of money, denoted y, paid at a delay of t, they would need to make indifferent to getting x dollars now. The same set of t is used as above, and the y subjects are allowed to choose is capped, with the maximum value defined by the set of y above (e.g. 10 dollars). The x in this question is determined as the minimum of the x-responses given in the first framing for a given y-value (e.g. x would correspond to the smallest x-value in all the responses to the block of questions in the first framing where $y = 10$).

Assuming risk neutral agents, Benhabib et al.(2010) [8], explain to the subjects that truthful reporting of the indifference value is the game theoretic optimal solution, if the payoffs are randomly drawn by a Becker-DeGroot-Marschak mechanism. This mechanism consists of randomly drawing a question out of the [*Q-present*]-barrage, and for the set of responses and parameters $\{x; y, t\}$, uniformly drawing a value from the distributon $U[0, y]$, such that

- if x is larger than the drawn value, then he does not get his indifference value and must wait a month for the full payout of y, or

- if x is smaller than the drawn value, then he gets more than his indifference value and is willing to accept the payout of the uniformly drawn amount now.

Intuitively, a risk neutral agent with true indifference value y_{ind} has no incentive to deviate and report a different indifference value. If he reports an indifference value y_{lie} less than y_{ind}, i.e. he understates his indifference, then there is a range of $y \in [y_{lie}; y_{ind}]$ that might be drawn with a positive probability where he is paid the drawn value now instead of being paid the full y later, even though this brings negative utility for him. If he reports an indifference value y_{lie} more than y_{ind}, i.e he overstates his indifference, then there is conversely a range of $y \in [y_{ind}; y_{lie}]$ that might be drawn with a positive probability where he is paid the full y later instead of being the drawn value now, even though, again, this brings negative utility for him. As such, it is only optimal to report the truth.

Econometrics. In this implementation, Benhabib et al. (2010) [8] obtain for each subject and for each barrage of questions a set of 30 observations in the form of money-time pairs $(x, 0)$ and (y, t). The risk neutrality allows them to assume the general relation between the variables here $x = yD(y, t)$[1], which can be estimated for both the present and the future framing, where the

[1] As our paper focuses on present bias exclusively, even though Benhabib et al. include an analysis for the magnitude effect (that the size of the choices affect the discounting), we do not include this in the exposition of the model here. This is not to say that analysis of the magnitude effect is irrelevant.

dependent variable is y and x respectively. The general econometric specification of the generalised discount function $D(y,t)$, as a function of the amount discounted y and the delay t, is thus:

$$D(y,t;\theta,\rho,\beta,b) = \begin{cases} 1, & \text{if } t = 0 \\ \beta d(t;\theta,\rho) - \frac{b}{y}, & \text{if } t > 0 \end{cases} \quad (17)$$

This function further nests a parametrised function of the canonical discount functions $d(t;\theta,r)$, with which the authors could test for the specific choice of discount model between exponential and hyperbolic,

$$d(t;\theta,\rho) = (1-(1-\theta)\rho t)^{\frac{1}{1-\theta}} \quad (18)$$

such that the full nested function over the set of parameters $\{\theta,\rho,\beta,b\}^2$, defined as follows:

a. θ, the **hyperbolicity** or **curvature** of the discount rate d: such that at the limit, the parameter values for θ code for either exponential or hyperbolic curvature in the absence of presence-bias, i.e. setting $\beta = 1$ and $b = 0$:

- $\theta = 1$ implies $D(y,t;1,\rho,1,0) = e^{-\rho t}$
- $\theta = 2$ implies $D(y,t;2,\rho,1,0) = \frac{1}{1+\rho t}$

b. ρ, the **discount rate**

c. β, the **variable cost** component of the present bias that is analogous to the β in the quasi-hyperbolic model. If $\theta = 1$ and $\beta < 1$, then the model has quasi-hyperbolic properties.

- $\theta = 1$ and $\beta < 1$, implies $D(y,t;1,\rho,\beta,0) = \beta e^{-\rho t}$

d. b, the **fixed cost** component of the present bias, which is Benhabib et al. (2010)'s [8] novel contribution to the model. When $b > 0$, then the model presents a present bias with fixed costs.

For instance, for a given x and t in the future framing, we obtain a y, such that the non-linear regression run has the following form:

$$x = y_i(x,t)D(y_i(x,t),t;\theta_i,\rho_i,\beta_i,b_i)\epsilon_i(x,t) \quad (19)$$

where the authors allow for individual specific parameters (modelisation and present-bias) and include an individual error term that depends on the given parameters of the question x and t.

Results. The regressions were run for both barrages under three specifications.

i. the regression was restricted to exclude present bias ($\beta = 1, b = 0$)

ii. the regression was restricted to include fixed cost present bias but exclude variable cost present bias ($\beta = 1$)

[2] while Benhabib et al. (2010) [8] use α for the variable component of the cost of present bias and r for the discount rate, to maintain consistency with the exposition in previous sections, these are relabelled as β and ρ respectively.

iii. the regression was unrestricted (both fixed cost and variable cost were included)

The key results of the model are as follows:

1. In both the present-framing and the future-framing, the average annual discount rate, derived from the distribution of ρ_i is 472%, which is comparable to the benchmarks in Thaler (1981) [50] when the differences in the range of monetary values are accounted for. This discount rate remains comparable under different specifications from other empirical papers.

2. In both the present-framing and the future-framing, a majority of agents have a θ significantly different from 1, i.e. **we can statistically reject exponential discounting**. This results holds strongly in (i), but at the expense of disproportionately high ρ-values; the result is slightly ambiguous in (ii) and ambiguous (iii). This is due to the fact that there is a tradeoff between robust identification of the form of present bias (between β and b) and that of the curvature of the discount function (between $\theta = 1$ and $\theta = 2$) as a result of front-end delay.

3. In the present-framing and the future-framing, the second specification (ii) obtains a fixed-cost present bias parameter value for b of around 4 and 2 respectively given reasonable ρ-values, and this value is significantly different from zero for all subjects. This speaks to a **presence of a present bias**. Under the third specification (iii), the authors obtain similar results for b of around 4 and 2, suggesting independence between the fixed and variable present biases. They also obtain a point estimate of around 0.92, and interval estimate with lower bound 0.84 at 95% confidence level, for the value of β, the parameter for the variable cost present bias. This has two implications: the **present bias is thus likely to be fixed-cost**, and thus this **rejects the quasi-hyperbolic model**.

4. Since the framing significantly affects the value of b, this speaks to a non-negligible effect of framing on the present bias. By comparing the cross-subject distribution of the estimates in each of the two barrages, the p-value of the Kolmogorov-Smirnov test is less than 0.005 for the hypothesis that θ, β and b are the same in both framings, and so **present or framing does play a significant role**.

The authors made sure to emphasise that the results in general lean towards a hyperbolic model with a fixed present bias cost, but argue that in general it is hard to conclude both the shape of the curvature and the form of the present bias, and that given their work was to prove the presence of a fixed cost in the present bias, it would appear that they prioritised identification of β and b over that of θ. However, this is not a particular issue for our analysis, since through the variables β and b elucidated here, we are able to draw significantly conclusions about the form of the present bias, and what we are interested in primarily is the existence of present bias. In sections 3 and 4, we will examine how to lean on the econometric method used in Benhabib et al. (2010) to establish the presence of present bias in the short-duration variation of their model.

2.1.5 Other Models

The four models above: exponential, hyperbolic, quasi-hyperbolic and the fixed cost discounting model by Benhabib et al. (2010) [8], while all vastly different in axiomisation and application, are similar in one important characteristic. The key assumption behind these models, and by those who developed them, is that the source of discounting comes is driven by varying modelisations of utility maximisation over a well-mastered set of choices. This is in sharp contrast with models that center on information-processing, including models of bounded rationality, attention, attribute-based preferences, reference-time theory etc., which derive greater inspiration from psychological empirical evidence about the interactions across numerous and distinct cognitive mechanisms. Since our model focuses on how smaller durations affect the present-bias, we continue to assume that agents have a full mastery of their choice set (which they do in the case our experiment), and thus informational concerns are not the top priority of our analysis and hence models based on these concerns do not form a substantial part of this literature review. Insofar as the change to smaller durations might interact with other informational models - such as through salience, is something we do not deal with directly. This will be discussed further in Section 5.

Our choice of the Benhabib model does not in any way speak negatively of a number of other models: the subadditive discounting model, which is a generalised model that examines changes in impatiences through lens of displacement of a fixed interval of time and (sub- or super-) additive properties of combinations of such intervals in a way to explain evolving preferences or subjective preferences over different intervals (Read, 2001) [44]; the vague time preferences model by Manzini and Mariotti (2006) [37], in which the choice between sooner and later money-time pairs is dependent on the clarity of the difference between the two, which leads to a three-step heuristic that prioritises utility valuation over monetary valuation over proximity, such that in identical bundles in two frames of time, the sooner one is chosen; and the more stylised intertemporal tradeoff model (Scholten and Read, 2010) [47], in which preferences are decided over the indifference between the gain of waiting longer for a higher value and the disutility of having to wait. Our choice of Benhabib's model is due to the fact that it lends most directly to an econometric analysis of the present bias we hope to identify.

2.1.6 Final Remarks

It is important to note that the distinction between the work of psychologists (such as Mischel and Metzner (1962) [41] for the hyperbolic discounting) tends to focus on how delay discounting is systematically different across subjects, and that this is usually a result of a number of societal (e.g. upbringing, social responsibility) and personal differences (e.g. age, intelligence) that need to be accounted for. This has a particular strong implication that individual preferences are inherently and systematically consistent for an individual, but are exogenously affected by these factors across time. As such, time is not considered to influence discounting, and there is again no room for inter-temporal inconsistency. At this juncture, while early empirical research has focused on finding a harmonised and unified *singular* representation of the human discount function, this has since given way to a more abstract modelling strategy in which axioms are defined in context-specific situations (gain vs. loss in prospect theory, temporal utilities vs. monetary utilities), and these principles tend to abstract from individual differences and relies heavily on econometric techniques to assume that the average across individuals is a consistent point estimator, and that this is sufficient in practice to ignore individual idiosyncrasies. (Grüne-Yanoff, 2015) [21]

Based on Benhabib et al. (2010)'s [8] results, one might be led to believe that hyperbolicity is the optimal way to proceed as the baseline in all experiments dealing with time preference. We caution readers against this: there is still little consensus on whether hyperbolic models are the sole or optimal model behavioural economists should adhere in time preferences. While it has the theoretical merits of sustaining preference reversals and present bias - as observed in the data, it also suffers from a number of shortcomings. Read (2001) [44] argued that the hyperbolic model (unlike the subadditive model he used, see above) fails to distinguish between the types of goods for which preference reversals are possible, which Loewenstein (1996) [33] calls "goods with visceral states" since they bring pleasure and pain (such as hunger, fatigue, arousal, etc.), and those for which this is generally not possible, such as money, which is then less significantly influenced by self-control issues. In that way, hyperbolic models ascribe impulsive behaviour to present bias, where it might in fact be due to the fact that some goods (hamburgers, as Read (2001) [44] cited) elicit self-control problems far more strongly than others (packs of A4 paper, Read (2001) [44]. In addition, there is conflation between self-control and discount factors that derive from the fact that when trade-offs between visceral goods are conducted between two periods in the future, these visceral goods generate a self-control issue now. In the same way alcoholics fall off the wagon because of a drink they want to have now (and not because of the big party tomorrow), the extra weight that self-control or the lack thereof puts on current period consumption ends up distorting the present-period valuations independently of the discount function, hence negating the need for hyperbolicity. Even if Read (2001) [44] proceeds to argue that these two failings could apply to money when money has a distinct visceral nature, for the purposes of our research, and in the view that the short durations of delay we put in place should reduce the salience of these visceral states (in that the present and the future states should not observe different visceral states), we will continue to work with the hyperbolicity model within the framework of Benhabib et al (2010) [8].

2.2 Waiting Time and Time Perception

The literature on waiting time has usually been split into two major categories: papers from the field of cognitive and neuro-psychology that focus on modelising the perception of time within the context of waiting, and more applied policy papers in the field of marketing, ergonomics and interior and urban design which focus on how waiting time affects consumer's (in the broader sense of the term for user) individual and social outcomes and the way consumers interact with their environment. For this latter case, we have a number of studies on how waiting time affects customer satisfaction at the cashier checkout, patient satisfaction in waiting rooms and emergency departments at clinics and hospitals, commuter satisfaction at bus stops, train stations and passenger terminals, etc. These papers accentuate the interaction between the time perception of the duration of waiting time and the ergonomic provision of facilities to alleviate the dissatisfaction or disutility engendered by waiting: this in turn is grounded in a number of cognitive principles derived from literature in the former case. The interaction of how applied public policy in these areas uses specific cognitive principles to achieve framing of the waiting time can serve as inspiration for behavioural economists who wish to frame wishing time in specific ways to test specific cognitive biases in economics. This is the same inspiration we take for our experiment here.

Canonical models of psychological time are generally divided into two categories: those that propose a sort of internal temporal pacemaker that regulates the passage of time, and those that propose cognitive factors that affect the experience and the perception of time, including the role of imagery, contextual changes, attention and cognitive capacity (Block-Zakay in Helfrich, 1996 [22]). In general, internal temporal models such as those by Treisman (1963) [52] account for an internal frequency with which we measure actual time, but do not account for the reasons for which this measurement might deviate in non-systematic ways (i.e. ways that do not depend on a singular failure of the 'pacemaker'). As such, further models expanded the model to include the pacemaker - still used for its unit measurement of frequencies - and the heuristic that individuals compare current experience with a benchmark previous experience (Church, 1984) [12]. Differences in this heuristic explain the non-systematic deviations; the most prominent cited difference is the attentional model of Thomas and Cantor (1975) [51]. The attentional model combines the previous two types of models into a weighted tradeoff between cognitive needs: the brain needs to simultaneously process information I, measured both in the unit interval frequency (a temporal information process, denoted $f(t, I)$, and in other cognitive processes, such as the recall in the Church (1984) [12] model, denoted $g(I)$. Perceived duration is then a function of these two information processes, weighted by a parameter α that measures the relative importance of one or the other; and anything that increases total (free) cognitive capacity tends to lengthen the perceived duration. While most of the experiments done here use durations in the order of magnitude of milliseconds, there is evidence for this to be valid at durations of most orders of magnitude (Michon, 1985) [40]. It is thus more than plausible that the information we feed - and the variations in quality and quantity of this information - will affect the perception of time. This is the core premise of the first phase of our experiment.

There are a number of principles in the psychology of waiting that are commonly used in the applied literature (Maister, 1984 [36]; Jardine 2017 [27]; Wu et al., 2013 [54]; Antonides et al., 2000 [4]; Norman, 2008 [42]), which are summarised quite briefly below. Only those that are relevant to our study of framing in terms of choice and time perception, but not in terms of general cognitive processing (linked to emotions and context), will be included below. As a preliminary statement, we can say that a general consensus exists on the fact that that while actual and perceived waiting have both theoretically and empirically been proven to be negative correlated with satisfaction and utility (Luo et al., 2004) [35], it is in fact the perception of time that dominates in predicting and explaining consumer choice behaviour (Baker and Cameron, 1996 [5]; Liu et al., 2009 [32]). As such the framing of the principles center on how time is perceived: two individuals waiting the same amount of the time may in fact be perceiving different durations and hence respond differently. For ease of exposition, Wu et al. (2013) [54] introduced a term for the perception factor, denoted φ, which is the ratio of the perceived waiting time t_p to the actual waiting time t_a.

$$\varphi = \frac{t_p}{t_a} \tag{20}$$

However, as we shall see, there is no cause to assume that φ is a linear relation between perceived waiting time and actual waiting time, so we write instead:

$$t_p = \varphi(t_a) \tag{21}$$

where φ is a unspecified possibly non-linear function. Because there is no direct method to measure perceived duration, we stress here that φ is not one of the variables of measurement in our model. However, it provides a handy analytical tool with which to compare effect of framings on perception of waiting time, and we will use it extensively to bridge between the theory in our model and the data we expect to collect from our experiment.

The main principles of interest to our paper are:

i. **Internal stability of time perception.** A general consensus in the literature is that cognitive processes surrounding time perception is an internal factor that is usually stable for individuals (Hornik and Zakay, 1996) [25]. While this is hard to prove and often cited as a shortcoming of these models, an extended caveat of this consensus is that this stability holds for at least the duration of the experiment, suggesting that we would not expect to see changes in cognitive ability for the actual time perception itself, nor changes in other cognitive factors that interacts with the cognitive perception, such that the subject remains internally consistent for the course of the experiment. This thus also precludes any 'learning' during the experiment.

ii. **Non-linearity in duration perception.** For shorter durations of less than one second, an increase in actual time is met with a proportional increase in perceived time, so the elasticity of φ is 1 (Fraisse, 1984) [18]; while for longer durations, there is marginal decrease in perception, i.e. as the actual duration gets longer, the marginal extra unit of duration is perceived shorter, so the elasticity of φ is less than 1 (Eisler, 1976) [17]. The latter case will apply for our experiment; indeed, Antonides et al. (2000) [4] estimated this value to be 0.84 in the context of a field experiment. Grondin (2001) [20] showed that subjective time, when measured prospectively (see principle vi), is proportional to the logarithm of true time; while Brocas and Carillo (2015) [11] showed instead in their time discounting experiment that there is a significant number of people who exhibit convex behaviour as well. The wealth of psychological literature has come to no consensus on this matter, as this is also subject to the experimental design used to elucidate these parameters.

iii. **"Start strong, end strong."** This is the time perception equivalent of the serial position effect (Ebbinghaus, 1913) [16], which states a well-established empirical fact in psychology: people tend to remember the start and end of experiences much better than the middle elements, and remember the relative position of the items at the start (primacy effect) and items at the end (recency effect) more strongly than the order of items in the middle. In the time perception environment, this implies that the salience of the beginning and the end of a duration is determinant for the perception of a duration.

iv. **Occupied time feels shorter than unoccupied time, $\varphi_{\mathbf{occ}} < \varphi_{\mathbf{unocc}}$.** The general consensus here is that if an individual is occupied, he pays less attention the passage of time itself and this reduces the perceived time (Hornik and Zakay, 1996) [25]. Other research has shown that increased complexity of the stimuli presented during a timer interval has attenuating effects on this reduction: complex stimuli increase perceived duration, while simple stimuli reduces perceived duration.

v. **Uncertain or unexplained waits feel longer than finite waits,** $\varphi_{\textbf{uncertain}} > \varphi_{\textbf{finite}}$. In general, the literature reports an overestimation of the duration of perceived waiting time when there is uncertainty about how long the duration will last. In conjunction with principle (ii), this overestimation is less strong in longer durations, which in the psycho-physical literature on time perception is any duration in the order of magnitude around 5 minutes or more. Any additional information then further attenuates the overestimation of the duration on the perceived waiting time as this reduces uncertainty (Kumar et al., 1997) [29]. Indeed, Antonides et al. (2002) [4] showed that information on waiting time reduces the perceived waiting time to the order of about 25%.

vi. **Prospective time is perceived longer than retrospective time**. Time perception is often depicted in the literature as either **prospective** or **retrospective**. In prospective perception, an individual is focusing on the passage of time in real time and hence directs more cognitive attention to the time, increasing its perceived duration (Zakay, 1989 [55]). On the other hand, in retrospective perception, an individual is not aware of the passage of time (either because there is no need to, or he was not framed to pay attention) during the actual duration itself, and is asked ex post to estimate the perceived duration from memory. As such, the perceived duration is dependent on the cues (meaningful events, (Zakay and Block, 1997) [56]) given to help commit the duration to memory during the duration, as they are taken as markers in the passage of time. (Hornik and Zakay, 1996) [25]. This then is linked to principle (iii) in terms of the quality of these cues. Block (2014) [9] then showed that on the basis of principle (iii), prospective durations are perceived longer than retrospective durations.

vii. **Counting down to the end leads to durations perceived as shorter than counting up to the end,** $\varphi_{\textbf{CD}} < \varphi_{\textbf{CU}}$ Shalev and Morwitz (2013) [48] showed that in general, when an individual is waiting for a duration to be completed while counting down, he is more likely to have shorter perceived duration that if counting up. This is due to the nature of the counting, as it is crystallises the goal of completion. The inverse is observed when the goal was framed as an accomplishment.

It is hard to transpose any of the quantitative results from psychology directly into our model because the experimental setups and focus of measurements are extremely different to those in our proposed experimental set up. That is, Brocas et Carillo (2015) [11] attempted to elucidate the relationship between time discounting and time perception by correlating data obtained from two different experiments, each testing one item, for a set of inexperienced subjects. Even though they do not find evidence of hyperbolic discounting (no present bias and low levels of impatience) in their time discounting task, there is substantial dispersion across the estimated values for the present bias (analogous to β in the Benhabib et al. (2010) [8] model, see Section 2.1.4), and the present bias has also been inflated by the uncertainty effect; this is indicative of most literature in this area. They also are unable to pin down fully the direction of inaccuracy in estimation (over or under), again indicative of the lack of consensus in principle (ii). The authors conclude that there is substantial individual heterogeneity across time perception that needs to be controlled for, but that there is still a generalised pattern observed.

Indeed, they show that subjects who tend to perceive a unit of time as longer are also less willing to delay the consumption of a reward by that time, i.e. show more sign of present bias (even if the authors argue there is no presence of hyperbolicity in their data). Mathematically[3], they determine that for an individual specific discount function $D_i(t)$ (here we abstract from magnitude effects), and a given perception function as defined by an individual specific φ_i of perceived time t_p as a function of actual time t_a, there is a time-weighting function $f(\cdot)$, which converts perception into discounting behaviour:

$$D_i(t) = f(\varphi_i(t_a)) \ \forall i \tag{22}$$

assuming that the perceived time and discounted time are in the same unit of time measurement. Then if we assume, as is empirically verified, that rewards are valued more now that in the future, that is as the interval between now and future grows, the rewards are valued less, then we have $f' < 0$, and by extension, that

$$\varphi_i(t_a) \gtrless \varphi_j(t_a) \Leftrightarrow D_i(t) \lesseqgtr D_j(t) \tag{23}$$

Empirically, this has been shown to hold for any duration between 1 hour and 1 day (due to the need to reconcile different durations in the two experiments the author conducted), and suggests that there is indeed a link between subjective perception of time and impatience, and that the ability of individuals to delay consumption is related to the mental representations of time delays between now and the future. The question now is to test this premise in the case of short durations, and show that if we are able to create specific heterogeneities in framing to test.

As such, based on the principles above, we have that in our experimental setup, we can say that, from principle (v), **we would expect a test subject waiting 10 minutes with no information (NI) to have a longer perceived duration than a test subject waiting 10 minutes with knowledge of that duration (I).** In our experiment, we are also relying heavily on the retrospective perception of the 10 minutes as an indicator of the delay they have to assess in the second phase of the experiment: as such, we expect the retrospective duration to reduce perceived time **on average** in the same way across all treatments. Block (2014) [9] also showed that the retrospective perception is usually affected in very limited ways by the relative changes in attention to internal time clocks. However, the inclusion of clocks that indicate of passage of time, and the subsequent externalisation of these cues, should, in a combination of principles (iv) and (vi), lead to there being a certain amount of prospective perception during the waiting phase as well that makes the passage of time more salient. As such, **we would expect both treatments with a clock to have a slightly longer perceived duration than that without a clock.** Finally, on the basis of principle (iii), the choice of the start and end of the externalised pacekeeping that a clock provides also have a framing effect on duration perception. In addition, using principle (vii), we postulate that **the treatment group with a clock that counts down (CD) from 10 minutes to 0 should lead to a shorted perceived**

[3]Again, the notation has harmonised with the rest of the literature review for ease of understanding

duration than the treatment group with a clock that counts up (CU) from 0 minutes to 10. In terms of φ, this leads to the following premise:

$$\varphi_{\text{NI}} > \varphi_{\text{CU}} > \varphi_{\text{CD}} > \varphi_{\text{I}} \tag{24}$$

The assumption we make here is that the effect of the absence or presence of information should be expected to dominate the framing around the presence of information. Then, by the premise in equation (23), we should observe that:

$$D_{\text{NI}}(t) < D_{\text{CU}}(t) < D_{\text{CD}}(t) < D_{\text{I}}(t) \tag{25}$$

This corresponds to what we expect, with most salience between the present and the future, and nothing to attenuate the effect of waiting, the present bias is the strongest in the framing with no information. Our experiment will attempt to put this to the test.

2.3 Short Durations

Precious little has been written in the field of economics about short durations when the order of magnitude is in the minutes and hours. The vast majority of economics literature on time preferences - including those mentioned above - work with days, months and years; and any extension of the literature to shorter durations has been done with a strong leaning towards neuroeconomic approaches that seeks to understand the cerebral subsections associated to different types of behaviour observed in discounting. Previous research has shown that the β-discounting (as seen in equation 11) is associated with the limbic reward areas (McClure et al., 2004) [38], which deal with the satiation of immediate and primal needs, often called "gratification", while the δ-discounting is associated with the prefrontal and parietal cortices, which are involved in the mechanisms of planning and deliberation (McClure et al., 2007) [39]. This neurological premise is thus a biological basis of the present bias, and has been shown to hold for the longer durations found in the empirical literature. Indeed, previous studies have shown that in addition to the activation of the prefrontal and parietal cortices, there is an additional activation of the limbic reward areas that might be indicative of the presence of present bias.

In one of but a few examples of literature on shorter durations, McClure et al. (2007) [39] had set out to corroborate these findings for shorter delays on the order of magnitudes of minutes, which is similar to those in our experiment. In particular, they ran an experiment in which thirsty subjects were asked to choose between R squirts of juice or water at delay D minutes and R' squirts of juice or water at delay D' minutes, where $R < R'$ and $D < D'$, $R, R' \in \{1, 2, 3\}$, $D \in \{0, 10, 20\}$, and the time difference, denoted $(D' - D) \in \{1, 5\}$. This implies that the possible delay-pairs (D, D') are $(0, 1); (0, 5); (10, 11); (10, 15); (20, 21); (20, 25)$, and the possible reward-pairs (R, R') are $(1, 2); (1, 3); (2, 3)$; and these are carried for either juice or water (with no internal mixing of liquid). Subjects were given 10 seconds to make choices, and received their reward, if any (as decided by their responses to previous choice questions), 15 seconds after the full loading of the screen, and were given 15 second to consume, and their responses as well as their cerebral activity were measured by a scanner. Focusing in on the results that explain their choices, the authors show that there is strong evidence of non-exponential discounting, in that there is a greater tendency to select the earlier reward at lower D (when 'sooner' is closer to the present), and when the time difference $(D' - D)$ is larger. This first finding is indicative of a present bias, and the second finding is indicative of an immediacy effect, which implies that the present bias is stronger when the difference between sooner and later is more salient. This is encouraging for our experiment, as these are indeed the two premises we want to test.

2.4 From Literature to Experiment

To conclude the literature review, we briefly remind our readers of the directions the literature has steered us in.

i. Hyperbolic discounting has been shown to relatively well explain the crossing of net present value curves, and thus explain present bias. Research in this is limited to long durations (days, months, years), and we wish to verify if this happens under short durations (minutes and hours).

ii. Shorter durations are also less problematic in the assumptions of risk neutrality and no conflating uncertainty, hence removing a lot of identification issues. Benhabib et al. (2010)'s [8] econometric specification allows to test these hypothesis for short durations.

iii. Literature time on waiting time and temporal perception argues that framing and information affect perception of waiting time. Indeed, a longer perception has been shown to be correlated with a stronger present bias. This allows us to derive different levels of information provision and framing to identify the types of cognitive salience are behind the presence of present bias. We thus use 4 different framings, as explained below.

iv. The dearth of literature in short durations (minutes) means that this is a version of the discounting empirical literature worth investigating.

3 Experimental Protocol

ALL FIGURES AND THE INSTRUCTION SHEET TO BE DISTRIBUTED TO SUBJECTS ARE IN THE **APPENDIX**

In this section, we will look at how the experimental protocol under Benhabib et al. (2010) [8] can be modified for shorter durations in which present-bias may not be expected to obtain. Additionally, to allow for the testing of the extent to which this lack of present-bias is due to a limited ability to perceive the difference between the present and the future, we propose several test groups which receive varying amounts of information about the passing of waiting time, and thus a more salient distinction between present and future.

The experimental subjects will be divided randomly into four treatment groups; each treatment group will differ in the amount of information about the duration and passing of treatment time in the first phase. Ideally, the experiment will be conducted for a group of between 40 and 60 students, so that each treatment group will have between 10 and 15 students. Each subject who comes for the experiment will be given an instruction sheet (see Appendix) detailing the form and procedure of the experiment. The experiment will be split into three phases:

1. **Waiting**. In this phase, the subjects will be divided into 4 treatment groups but will be asked to stare at a blank screen for 10 minutes. The difference between the 4 treatment groups lie in the information they are given during this 10 minutes, as follows:

   - Treatment NI: This group is not informed about the duration of the waiting time they will have to sit through. Their screen will read: "*You must now wait.*"
   - Treatment I: This group is informed about the duration of the waiting time they will have to sit through by a statement on their screen: "*You must now wait 10 minutes.*"
   - Treatment CD: This group is informed about the duration of the waiting time they will have to sit through by a statement on their screen: "*You must now wait 10 minutes.*" Additionally, they will be provided with a digital count-down timer under this statement that starts at 10:00 and runs down to 0:00.
   - Treatment CU: This group is informed about the duration of waiting time they will have to sit through by a statement on their screen: "*You must now wait 10 minutes.*" Additionally, they will be provided with a digital count-up timer under this statement that starts at 0:00 and runs up to 10:00.

   For all treatment groups, the screen will indicate at the end of 10 minutes that their waiting time is over: "*Thank you for waiting*.". This screen does not contain any indication about the duration they had waited, such that subjects in treatment NI are never informed that they had waited 10 minutes.

2. **Elucidating Preferences**. In this phase, we adopt an approach not dissimilar to the one taken in Benhabib. et al (2010) [8] with the key modifications of using multiples of the waiting time each of the subjects had experienced in phase I, designed thus to be of short orders of magnitude, instead of time periods that range from days to months. To ensure that the temporal dimension (present-bias) is visible and not drowned by the magnitude of the reward, we also scale the reward by a factor of 10, using thus a reward vector that runs from 1€ to 10€. Subjects will be asked to input an answer x to each question in a battery of 30 questions, each of the following form:

   What amount of money, €x, if paid to you now, would make you indifferent to €y paid to you after waiting t?

   The five values of y ranged from 1, 2, 3, 5 and 10; while each of the six values of t is defined as a multiple of the waiting time they had previously experienced in the previous phase, and are denoted as follows:

   - *... the **same** duration you had waited in the previous phase*;
   - *... **twice** the duration you had waited in the previous phase*;
   - *... **thrice** the duration you had waited in the previous phase*;

- ... ***six*** *times the duration you had waited in the previous phase*;
- ... ***half*** *the duration you had waited in the previous phase*;
- ... ***a quarter*** *of the duration you had waited in the previous phase*

This translates to $t = 10, 20, 30, 60, 5$ and 2.5 minutes in each respective case. For instance, a typical question a subject could face would be the following:

What amount of money, €x, if paid to you now, would make you indifferent to €5 paid to you after waiting twice the duration you had waited in the previous phase?

This type of question is denoted as [*Q-present*] in Benhabib et al. (2010) [8] and is in juxtaposition to an alternative battery of questions they had proposed, denoted then [*Q-future*]. In [*Q-future*], the main premise is to ask subjects how much they are willing to accept y after a given time to make them indifferent to accepting x now. In Benhabib et al. (2010) [8], the key premise behind including the two different types of framing is to allow the authors to identify the type of present bias (fixed or variable cost). In our case, our key interest is however on whether present bias exists and not the type of present bias there is, so we do not make this distinction for our experiment, and use only the [*Q-present*] framing.

3. **Payoffs**. The Becker-DeGroot-Marschak mechanism is designed to determine the amount and time at which a subject should be paid. This is done in such a way that, under risk neutrality, it is a dominant strategy for subjects to report their true indifference amounts. The subjects are fully briefed about the mechanism behind the Becker-DeGroot-Marschak mechanism, and it is assumed that they have fully understood its implications on their strategy. The procedure is as follows:
   - For each subject, one of the 30 questions answered in phase 2 is drawn randomly and will serve as the basis of the Becker-DeGroot-Marschak mechanism.
   - For the question drawn, the experimenter will have the following information set $\{x, y, t\}$ that corresponds to the indifference amount x the subject had indicated, the amount y he would receive after waiting the duration t.
   - Using this information, a random value $\tilde{y}$ is drawn from a uniform distribution $U[0, y]$. The payoff structure is then determined as follows:
     - if $\tilde{y} > x$, the subject collects $\tilde{y}$ now.
     - if $\tilde{y} < x$, the subject will wait the duration t for y.
   - If the subject has to wait, he will be asked to sit in the testing area. This time can be used to test other hypotheses, run concurrent experiments, etc. The essence is that the subject has no control over or choice in what activities he will do at this period, and will not be paid for participating while waiting. There is no incentive thus involved in the extra wait.
   - In both cases, the subject will receive - either now or after duration t, a full cash payout. Since this is true for both subjects who collect the money now, and collect the money in t, and the durations are short, and they had to wait to collect the future payment anyway, we assume there is no transaction cost and thus it will not figure in the decision making of subjects.

4 Hypotheses and Proposed Empirical Treatment

In this section, we will elaborate on the data that we will obtain from the experimental procedure and explain the econometric structure, inspired again by Benhabib et al. (2010) [8], that this data will fit into. In particular, we will list a number of hypotheses we would expect to observe in the data, pertaining to both present bias in short durations and the role of salience in this bias.

Data Treatment. The data we expect to collect is for between 40 and 60 subjects, divided into four treatment groups of between 10 and 15 subjects each, with each group receiving a different framing treatment for the passage of their 10-minute waiting time. Because the time preferences we are trying to elucidate are for short durations in all four groups, for the econometric manipulation pertaining to only the effect of short durations on the present bias, the grouping is irrelevant, and we can treat the full cohort of subjects as one group. However, the existence of the four treatment groups allows us to (plausibly) generate different present biases in each group, and we shall be exploiting these differences in framing and between-cohort differences in present bias to look at the role of salience in present bias. For ease of treatment, we will only index for the groups when needed.

As with Benhabib et al. (2010) [8], we expect that there is a certain amount of heterogeneity across subjects, indexed $i = 1, \cdots, N$, and for each subject, we have a set of 30 money-time pairs $\{x(y,t); y, t\}_i$, where we denote $x_i(y,t)$, the 30 indifference amounts indicated to the experimental question for a given y to be obtained with a delay t. As such, we can run for each individual i a non-linear least squares regression, inverting the form used in Benhabib et al. [8][4]:

$$y = x_i(y,t) D_i^{-1}(y, t; \theta_i, \rho_i, \beta_i, b_i) \epsilon_i(y,t) \tag{26}$$

where, as a reminder, we have the following function forms:

$$D_i(y, t; \theta_i, \rho_i, \beta_i, b_i) = \begin{cases} 1, & \text{if } t = 0 \\ \beta_i (1 - (1-\theta_i)\rho_i t)^{\frac{1}{1-\theta_i}} - \frac{b_i}{y}, & \text{if } t > 0 \end{cases} \tag{27}$$

and an independently and identically distributed error term ϵ for each subject that is such that $E[\epsilon | D_i(\cdot)] = 0$, or that the error term s uncorrelated with the non-linear function of y and t. With this regression, we then obtain the individual-specific parameters $\theta_i, \rho_i, \beta_i, b_i$ that defined the functional form of each individual's discount function $D_i(\cdot)$. Notice that, unlike in Benhabib et al.(2010) [8], the dependence of $D(\cdot)$ on y is now on a given parameter and not a response to a question, and is likely subject to less noise. Additionally, since we are only interested in the existence of the present bias, but not the shape of it, we do not make additional parameter restrictions in an attempt to isolate the separate effects of the fixed and variable present biases.

Key Premises. We obtain thus a set of parameters $\{\theta_i, \rho_i, \beta_i, b_i\}$ for each of our subjects. At this juncture, we recall the two key premises we would like to test through this experiment.

[4] The inversion is valid since $D(\cdot)$ is non-zero, since y is non-zero, and is monotone

- **Premise 1 (Present Bias).** As the experiment is conducted with shorter durations, reducing the salience of the distinction between the present and the future, we expect there to be **a reduced present bias** compared to that found in Benhabib et al. (2010) [8]
- **Premise 2 (Salience).** Restoring salience between the present and the future would restore - partially - the present bias. This depends on the framing at hand: the present bias should be the largest with no information (longest due to the uncertainty effect), followed by information accompanied by a clock that counts up (which lengthens the perceived duration), followed by information accompanied by a clock that counts down (which shorterns the perceived duration), followed by unaccompanied information (where the there is no externalisation of clocks to correct for underperception).

$$PB_{\text{NI}} > PB_{\text{CU}} > PB_{\text{CD}} > PB_{\text{I}} \tag{28}$$

We also recall that the measures of present bias in our model are β and b. Even though the former measures variable-cost present bias and latter measures a fixed-cost present bias, our goal here is not to distinguish the two, but to identify whether there is **a** present bias, and if yes, of what scale it is, regardless of its type.

Hypotheses on Present Bias in Short Duration. We can then at this preliminary stage run the following hypothesis testing procedures to check if our data corroborates with our basic premise that there may be an absence of present bias. This entails:

- **Hypothesis 1.** *Absence of Present Bias*
  For each subject i,

$$H_0^1 : \begin{bmatrix} \beta_i \\ -b_i \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{29}$$

$$H_A^1 : \begin{bmatrix} \beta_i \\ -b_i \end{bmatrix} < \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{30}$$

  Notice that we take negative b so that the sign of the alternative is valid for both elements, but this does not change the sense of the hypothesis since the null value associated to b is 0. We used the joint-significance test since rejecting the hypothesis implies that either $\beta < 1$ or $a > 0$, either of which alone would indicate the presence of a present bias.

From this hypothesis, the proportion of subjects that do not reject the hypothesis of the absence of present bias will give us a first indicator of whether our first premise is true. Further, if we assume that the subjects' discounting behaviour are not correlated by interactions between individuals (it is for this reason, we want to minimise contact between individuals during the lab session) and that observed differences across these parameters are determined by individual fixed effects, then further assuming these individual fixed effects are randomly drawn from the same distribution such that in aggregate they cancel out, we can use the mean for this set of parameters as a basis for comparison. In particular, recall that Benhabib et al.(2010) [8] found that in the Q-present framing with no restrictions (as we had used), the mean value of b was found to be roughly 1.7, and mean of β to be roughly 1. For our premise (1) to be true, we would require that mean b in our experiment be lower than 1.7 and that mean β in our experiment remain at 1 (i.e. still no variable-cost present bias).

- **Hypothesis 2a.** *Reduced Fixed Cost Present Bias.*

$$H_0^{2a} : \bar{b} \leq 1.7 \tag{31}$$

$$H_A^{2a} : \bar{b} > 1.7 \tag{32}$$

- **Hypothesis 2b.** *Maintained Absence of Variable Cost Present Bias.*

$$H_0^{2b} : \bar{\beta} = 1 \tag{33}$$

$$H_A^{2b} : \bar{\beta} \neq 1 \tag{34}$$

For our first premise to hold, we would expect both hypotheses to not be rejected.

Hypotheses on the Role of Salience. If we maintain that the first premise is true, then we can examine the role of the different framings in the different treatment groups on the present bias at hand. Again, assuming that all the participants come from the same distribution of individual fixed effects such that in aggregate, we expect them to not be significantly different across treatment groups, we can cluster the data by subject according to their treatment group and calculate the means in a similar way to that above. Using the index for the treatment groups NI, CU, CD and I, we should obtain the mean β and mean b for each treatment group.

Treatment Group	*Mean Fixed Cost PB,* $\bar{b}$	*Mean Variable Cost PB,* $\bar{\beta}$
No Information, NI	$\bar{b}_{\text{NI}}$	$\bar{\beta}_{\text{NI}}$
Information, I	$\bar{b}_{\text{I}}$	$\bar{\beta}_{\text{I}}$
Information + Countdown Clock, CD	$\bar{b}_{\text{CD}}$	$\bar{\beta}_{\text{CD}}$
Information + Countup Clock, CU	$\bar{b}_{\text{CU}}$	$\bar{\beta}_{\text{CU}}$

Table 1: Notation for treatment-specific mean present-biases

The hypotheses are thus:

- **Hypothesis 3.** *Lack of Informational Salience Encourages Present Bias.*

$$H_0^3 : \bar{b}_{NI} - \bar{b}_I \geq 0 \tag{35}$$

$$H_A^3 : \bar{b}_{NI} - \bar{b}_I < 0 \tag{36}$$

- **Hypothesis 4.** *Passage of Time Salience Encourages Present Bias.*

$$H_0^4 : \begin{bmatrix} \bar{b}_{CU} - \bar{b}_I \\ \bar{b}_{CD} - \bar{b}_I \end{bmatrix} \geq \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{37}$$

$$H_A^4 : \begin{bmatrix} \bar{b}_{CU} - \bar{b}_I \\ \bar{b}_{CD} - \bar{b}_I \end{bmatrix} < \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{38}$$

- **Hypothesis 5.** *Counting Up Encourages Bias More than Counting Down*.

$$H_0^5 : \bar{b}_{CU} - \bar{b}_{CD} \geq 0 \tag{39}$$

$$H_A^5 : \bar{b}_{CU} - \bar{b}_{CD} < 0 \tag{40}$$

The null hypotheses of each of these three tests are those found in premise 2, and we expect them - as per our literature review - to not be rejected. However, inherent to premise 2 is the assumption that information quantity is more important to the framing of the information (as mentioned in Section 2). Using the data we have, we can test for whether this assumption is true; here we neither expect the null hypothesis to be rejected or otherwise, but the results of this test will have strong policy implications.

- **Hypothesis 6.** *Lack of Informational Salience Encourages Present Bias More than Passage of Time Salience*.

$$H_0^6 : \begin{bmatrix} \bar{b}_{NI} - \bar{b}_{CU} \\ \bar{b}_{NI} - \bar{b}_{CD} \end{bmatrix} \geq \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{41}$$

$$H_A^6 : \begin{bmatrix} \bar{b}_{NI} - \bar{b}_{CU} \\ \bar{b}_{NI} - \bar{b}_{CD} \end{bmatrix} < \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tag{42}$$

If we reject this hypothesis, it would imply that passage of time salience is more important that the lack of information, which would lead us to conclude that what drives present bias is not so much the factual information about the waiting time but rather the temporal experience. This would further imply that present bias is driven not by a quantitative discounting measure, but by informational and cognitive biases, and as such perhaps would explain why a purely quantitatively-parametrised model of discounting, such as the quasi-hyperbolic or the fixed-cost model in Benhabib et al. (2010)[8], do not achieve much universal fit.

5 Discussion

In this section, we will shift focus onto how the two novel additions to the Benhabib et al. (2010)[8] model might be extended, and some of the shortcomings that need to be addressed for more robust results. These are divided into three sets of concerns: theoretical, experimental and econometric concerns. Where possible, we will provide possible solutions to address these concerns. In addition, we will look at some ways this research can be applied to behavioural public policy, shaping the way, for instance, we look at waiting time in consumer settings.

5.1 Theoretical Concerns

Uncertainty. One of the key critiques levied towards experiments conducted on time preference is that over long durations, it is likely that present bias is both a result of a mixture of some form of preference for instant gratification (in the form of a (quasi-)hyperbolic discounting, for instance) and some form of risk aversion towards uncertainty. Experiments that only tested for time preference without looking at how it interacts with risk thus do not fully explain the source of this present bias. Indeed, Andreoni and Sprenger (2012) [3] show that if certain and uncertain utility are measured differently (subject to ”differential assessments”, such as different utility function curvatures), then the presence of uncertainty can indeed explain some of the present-bias behaviour due to some form of probability weighting over current and future consumption. However, if uncertainty is also an increasing function of the delay, then at the short durations we propose in our experimental protocol, we do not expect the uncertainty to play a big role. However, since Benhabib et al. (2010) [8] did not control for uncertainty, there is substantial room to be concerned that the reduced salience between the present and the future that leads to the difference between the present bias observed in the Benhabib et al.(2010) [8] study and our study does not act through discounting, but rather through the reduction in uncertainty. A further study to look into this difference would then be needed to distinguish the effects.

Fungibility of Money. Although there is a substantial literature using non-monetary rewards, a majority of papers uses money (actual or virtual) as rewards in experiments on time preferences. The concern wth using money, as is often noted, is that it is **fungible**, which implies that individual units of money are easily interchangeable. This property makes the immediacy of any reward hard to guarantee, because an agent who receives money now does not necessarily need to spend it now; it also makes the future reward (especially across long delays) less attached to its delay, since individuals can anticipate and spend the reward money earlier than thought. As such, this makes the measurement of the temporal aspect difficult, and would make identification of the present bias. This is not a critique that our paper escapes from, and there are few econometric solutions since the degree of fungibility and the extent to which immediate outcomes are perceived as some weighted average between actually-immediate outcomes and partially-immediate (consumption happens at $t = \epsilon > 0$) outcomes is usually not observable. Experiments that use monetary rewards that must be immediately consumed at the point of reception (such as same-day or same-hour vouchers that must be spent on the given day or in the given hour for objects that individuals already want) might be an interesting avenue to explore.

Primary Rewards vs. Secondary Rewards. In addition to fungibility issues of money, it is a well-known premise in the psychology of conditioning that primary (food and liquid) and secondary (money) rewards have differential effects on cognition. Beck et al. (2010) [7] showed that reward incentive might be subject to a category effect depending on whether money or juice is offered. This then acts on different parts of the brain, in that monetary rewards require additional specialised neuronal mechanisms that are not called upon for primary rewards. Indeed, the authors suggested that the longer fungibility of money leads to a sustained activation in cognitive control regions that might lead an increased salience of the value of this money, that one does not get with perishable and thus immediately consumed primary rewards that lead to temporary activations in the brain. This additional element means that money as a good in itself has inherent properties that delays gratification; while primary good do not. Indeed, Holt et al. (2016) [24] found that food outcomes, a primary reward, are discounted more steeply than monetary outcomes, a secondary reward, and that the discount factor is negatively dependent on the perishability and positively dependent on the fungibility. The consequence of this research is that not only does the usage of monetary rewards tend to underestimate the present-bias, the valuation of money is then also extremely susceptible to the context in which it is earned, and this adds additional noise to the model. A replication of our proposed model to use the juice-dispensing mechanisms found in McClure et al. (2007)[39] might give us further insight to the interaction of present-bias and short durations in non-monetary contexts, which may indeed be a more accurate representation of the time preference situations economic agents find themselves in when thirsty, hungry or lascivious (and thus in need of a primary reward).

5.2 Experimental Design Concerns

Magnitude Effects. One of the key differences between the experimental protocol in Benhabib et al. (2010) [8] and our protocol is that we chose explicit to not look at magnitude effects (i.e. discounting declines with the amount to be discounted). However, it is not unreasonable to assume that given sufficiently large amounts y to be given in a short delay would make the experiment meaningless, so we intentionally scaled down the size of the rewards so that we are sure it does not influence or obscure the present bias. However, by not controlling for the magnitude effect (i.e. not making a distinction between the fixed and variable cost of the present bias), we are still not sure whether there is a magnitude bias at this new order of magnitude (units and tens) for the rewards. As we do not yet have the data from the experiment, we are unable to plot the graph of the discount factor against the amounts y, and hence we are unable to determine where there is a magnitude effect. If we were to observe a magnitude effect, a new IV specification will be needed to properly isolate the value of β and b in the discount function in the regression, since then there will be endogeneity due to the non-zero correlation between the value of y and the value of the error, which violates the orthogonality condition of the non-linear least squares model.

Cognitive Deficiencies in Assessing Delays. One of the consequences of our choice of framing is that we require subjects to retrospectively recall the waiting time they had just gone through, and then to use assess their time preferences based on delays that are multiples of that interval for which they had just waited. This leads to two problems: firstly, it has been shown that accuracy of temporal judgments for intervals is dependent on the difficulty of the concurrent processing tasks at hand; and secondly, this dependency is heterogeneous. This implies that conditional on how strong an individual's cognitive aptitude for measuring his own indifference, we will observe different levels of interference with the recall on the perception of time, adding substantial heterogeneity and thus noise to the data generating process for our present bias. Unfortunately, because our framing relies on obscuring information about the duration of the interval for one of four of our treatment groups, we cannot ask all four groups to participate in a prospective version of the waiting experiment in such a way as to concurrently have them wait while conducting the questions on the waiting time they would be going through then. As such, a possible extension would be to run an experiment in the post-questionnaire waiting time in which they are made to do other related tasks that elucidate their ability to make temporal judgments while doing other tasks, as an approximation for the cognitive difficulties they might have. Controlling for these difficulties might then allow us to get a better estimate for a limited sample of our subjects whose Becker-DeGroot-Marschak draw required them to wait.

5.3 Econometric Concerns

Individual Fixed Effects and Enforced Homogeneity. This particular concern is perhaps the most important of all the shortcomings of the empirical analysis we propose to conduct on the experimental data. It is clear that we cannot have one subject sit for all four treatments, so the treatment groups - like in all empirical exercises with different treatment - will suffer from some level of between-group heterogeneity. One of the central assumptions that allows us to aggregate and take means across subjects is that we assume that their individual fixed effects are all individually drawn from the same multivariate distribution of fixed effects, and as such when taking the average, we assume that the aggregation across different individuals should sufficiently cancel out the differences across individuals. If this were the case, then we can posit that the conditional averages ($E(\bar{b}|X_1, \cdots, X_n)$, where X is the vector of individual characteristics affecting discounting) is the same as the unconditional averages $E(\bar{b})$. It is instantly clear that this is an extremely strong assumption about the distribution of individuals; in fact, it would require that the sample we constitute be as unrepresentative in individual characteristics as possible, while as representative of the present-bias behaviour independent of inidivudal characteristics as possible, which is very unlikely. This becomes of particular concern when we compare across our treatment groups, since it entails that we assume the unconditional mean present-bias to be distributed across the treatment groups in the same way the conditional mean present-bias would be. If this were not the case, none of our hypotheses can be robustly examined.

One perhaps unorthodox solution might be to run a clustered regression clustering all individual regressions for each of the 60 subjects along with a dummy for which treatment group they are in. If robust, this particular non-linear regression will isolate the effect that comes from being in a specific treatment group on the discount function, leaving the b that is estimate to be due entirely to individual fixed effects. This gets round the issue of having to identify all the individual fixed effects but does not allow us to identify the value of the present-bias parameter. However, if we are willing to assume specific functional forms and identification conditions on the other parameters θ and ρ, notably through a fixed discount curvature such as hyperbolic or exponential, we can then identify a joint-conditional b and β vector, given a specific treatment group and a specification for the discount function. We can then run these regressions for several discount function specifications and provide specification-specific conclusions about the present bias. An issue with this would be that specifications also restrict the types of present bias we are allowed, shifting weight arbitrarily between the fixed-cost present bias and the variable-cost present bias. That said, we would still have identified the presence of a present bias in the form of a jointly-estimated β and b vector. The literature on this remains quite sparse, and such an approach, to the best of our knowledge, has yet to be done.

Power. Finally, an age-old critique on empirical economics would be on the effect of a limited sample size on the power of the statistical tests we intend to perform. Power is the the probability of a test of making a correct rejection. Indeed, there is a tradeoff here between gathering a large sample size in order to boost our tests, and adding additional heterogeneity in the model that is at the heart of the strong assumptions made in the previous subpoint. As such a larger sample simultaenously brings more accuracy to the the testing of hypotheses we want to examine, but at the expense of making the heterogeneity even more difficult to control for. Because each experimental setup is different, there is no conventional standard optimal sample size, the tradeoff does imply that we cannot simply increase the sample - within the limits of our logistical ability - to increase the power and accuracy of our tests. This problem is exacerbated by the fact that the differences between treatments we are measuring are expected to be quite fine, and so a low power might fail to reject a null of equality between two treatment groups when it should; this is a major problem for identification of the salience effects.

5.4 Application to Behavioural Policy

One of the main motivations for this paper was to examine the way in which we can adjust existing literature on time preferences to examine shorter delays; we feel that our experiment would have given us interesting insight. However, even if this was not part of our main purpose or design, these insights might be applicable to the world of behavioural public policy. Indeed, one of the main flaws of using this existing literature as the generic theoretical basis is that while the literature uses long durations, the context in which the findings are applied are not always of the same temporal frame. That is to say, findings on the existence of present bias, on magnitude effects, or any cognitive bias in time preferences tend to be extracted from studies modelling long periods, and while these are applicable to long-term policies such as inducing savings and health behaviour, these might not be applicable to the consumer context of today, especially when decisions about making non-investment goods (non-durable) tend to not stretch over many days, let alone many months. As such, marketing and consumer behaviour experts might benefit from experimental literature that modifies the canonical experiment time frame to hours and minutes, which is what our paper attempts to do.

We can imagine that situations that exploit impulsive behaviour (due to the present bias assumed to be present in the decision making of individuals) might benefit from understanding how the proximate 'future' (i.e. short delays) might reduce the need to be impulsive - people might indeed be patient enough to wait for an hour, when they might not be willing to wait for a day. This in turn might inform policy in situations such as that in Singapore, where private commuters choose when and how to enter the central business district, access to which is governed at peak hours by an additional congestion surcharge ERP. While ERP has gone up substantially over the years in a drive to blanketly discourage individuals from driving in the city at peak hours, one observes the phenomenon that many drivers hold back from entering the city (i.e passing through gantries) around these peak hour thresholds, often indicated as a fixed time (say 8pm) on the gantries. That is to say they prefer at short intervals before the threshold the bundle of (utility of entering the city, in a short delay) over (utility of entering the city - the surcharge, now); while at long intervals before the threshold, this is the reverse. There is thus indeed present bias here that indicates a difference between short and long interval; which means that above a certain interval duration, the congestion surcharge is ineffective. We can then ask to when an interval transforms from being perceived as 'short' to being perceived as 'long', and how we can adjust surcharges at the long intervals to make the congestion surcharge more effective.

Similarly, our work on salience could also be useful in furthering research on customer satisfaction in waiting time. While most papers on consumer behaviour have focused on reported customer satisfaction levels due to specific framing methods of the time they had to wait, little has been done about how that framing affects choices. Indeed, in situations where shortages or excess demand are frequent - such as in public transport, we can imagine a situation in which customers have to choose between several limited trains departing with different delays. This could be choosing to fight to board a full subway 3 minutes from now, or wait 10 minutes for the next subway. The framing of the delay between trains might help to reduce congestion by pushing sufficiently patient individuals to board the next train. While in Paris, this indication is often two delays displayed one after the other (3; 10), this sufficiently provides information about the delay to the next train; whereas in some metro systems, such as those in Berlin and Budapest, only the next train's arrival time is shown, with no indication of delay. We might then ask if the additional salience provided in Paris helps spread out commuter flows; if so, then urban ergonomics of waiting time design at public transport hubs would benefit from knowledge of how framing of delays quantitatively affect intertemporal commuting choices. This would be an interesting direction to explore.

We believe that there are numerous daily situations in which choices are made over short intervals, and yet the literature in empirical and behavioural economics on this has been rather sparse. We thus hope that our paper can contribute to building a foundation for choice-decision models for consumer behaviour at more realistic time frames.

6 Conclusion

This paper was designed to propose two novel additions to the existing literature on present-bias. While there is no clear consensus in literature as to how to model present bias, we chose Benhabib et al. (2010)'s [8] model for its experimental simplicity and economic tractability in isolating two factors for present bias. Based on their results that there is a hyperbolic discounting that generates present bias through a fixed cost, we propose to run a similar experiment replacing the longer durations (months and days) with shorter durations to see if the present bias is maintained at shorter durations. Indeed, if we expect that present bias is due to the discounting across two distinctly different periods of the present and the future, then any delay interval over which this distinction cannot be made would be expected to not show as much present bias. This is thus our first premise: shorter delay intervals reduce present bias.

In addition, we argued that salience can take multiple forms and propose a waiting time treatment in which we divide the participants into 4 treatment groups each with a different quantity or quality of information. We hypothesise that reducing information about the duration to wait will make the future more salient since waiting feels more protracted, and thus restore the present bias partially; while increasing the salience about time's passing will also make the waiting feel protracted, again restoring the present bias. We also posited the salience that comes from quantity of information about the duration to wait has a strong effect on the present bias than the passage of time. We used Benhabib et al. (2010)'s [8] non-linear specification for a discount function to elucidate a number of individual and aggregate parameters about present bias and propose a series of hypothesis to test that would support our posits above.

We also acknowledged that there are a number of theoretical, experimental and empirical concerns inherited from the model of Benhabib et al. (2010) [8] and brought about by our additions that need to be addressed. These include the inherent endogenous role of money in the discounting, cognitive deficiencies in estimating time and individual heterogeneities: for each of these, we proposed a preliminary solution that might also act as future directions research can be taken in. Finally, we looked at a few ways in which our research might benefit behavioural public policy both through its conclusions on short duration and on salience. We believe that results of this experiment has the potential to cast further light on how individuals reacts to instantaneous and short-term gratification possibilities, and will help eventually answer the age-old question: ”when does the future start, and how do we know when it does?”. It is our hope that this research will be the foundation for further research on the role of salience in distinguishing the present and the future.

Bibliography

References

[1] George Ainslie. “Specious reward: a behavioral theory of impulsiveness and impulse control.” In: *Psychological bulletin* 82.4 (1975), p. 463.

[2] George Ainslie and Richard J Herrnstein. “Preference reversal and delayed reinforcement”. In: *Animal Learning & Behavior* 9.4 (1981), pp. 476–482.

[3] James Andreoni and Charles Sprenger. “Risk preferences are not time preferences”. In: *American Economic Review* 102.7 (2012), pp. 3357–76.

[4] Gerrit Antonides, Peter C Verhoef, and Marcel van Aalst. “Consumer perception and evaluation of waiting time: A field experiment.” In: *Journal of Consumer Psychology* (2002).

[5] Julie Baker and Michaelle Cameron. “The effects of the service environment on affect and consumer perception of waiting time: An integrative review and research propositions”. In: *Journal of the Academy of Marketing Science* 24.4 (1996), p. 338.

[6] Uttara Balakrishnan, Johannes Haushofer, and Pamela Jakiela. *How Soon Is Now? Evidence of Present Bias from Convex Time Budget Experiments*. Tech. rep. National Bureau of Economic Research, 2017.

[7] Stefanie M Beck et al. “Primary and secondary rewards differentially modulate neural activity dynamics during working memory”. In: *PloS one* 5.2 (2010), e9251.

[8] Jess Benhabib, Alberto Bisin, and Andrew Schotter. “Present-bias, quasi-hyperbolic discounting, and fixed costs”. In: *Games and Economic Behavior* 69.2 (2010), pp. 205–223.

[9] Richard A Block. *Cognitive models of psychological time*. Psychology Press, 2014.

[10] Richard A Block and Dan Zakay. In: *Time and mind* 33 (1996), pp. 171–195.

[11] Isabelle Brocas, Juan D Carrillo, and Jorge Tarrasó. “How long is a minute?” In: (2015).

[12] Russell M Church. “Properties of the internal clock”. In: *Annals of the New York Academy of Sciences* 423.1 (1984), pp. 566–582.

[13] Maribeth Coller, Glenn W Harrison, and E Elisabet Rutström. “Are Discount Rates Constant? Reconciling Theory and Observation”. In: (2005).

[14] Sanjit Dhami. *The Foundations of Behavioral Economic Analysis*. Oxford University Press, 2016. Chap. 9–11.

[15] John R Doyle. “Survey of time preference, delay discounting models”. In: *Judgment and Decision Making* 8.2 (2013), pp. 116–135.

[16] Hermann Ebbinghaus. “Memory (HA Ruger & CE Bussenius, Trans.)” In: *New York: Teachers College.(Original work published 1885)* 39 (1913).

[17] Hannes Eisler. “Experiments on subjective duration 1868-1975: A collection of power function exponents.” In: *Psychological Bulletin* 83.6 (1976), p. 1154.

[18] Paul Fraisse. “Perception and estimation of time”. In: *Annual review of psychology* 35.1 (1984), pp. 1–37.

[19] Shane Frederick, George Loewenstein, and Ted O'donoghue. "Time discounting and time preference: A critical review". In: *Journal of economic literature* 40.2 (2002), pp. 351–401.

[20] Simon Grondin. "From physical time to the first and second moments of psychological time." In: *Psychological bulletin* 127.1 (2001), p. 22.

[21] Till Grüne-Yanoff. "Models of temporal discounting 1937–2000: An interdisciplinary exchange between economics and psychology". In: *Science in context* 28.4 (2015), pp. 675–713.

[22] Hede Helfrich. *Time and mind*. Hogrefe & Huber Pub, 1996.

[23] Richard J Herrnstein. "On the law of effect". In: *Journal of the experimental analysis of behavior* 13.2 (1970), pp. 243–266.

[24] Daniel D Holt et al. "The domain effect in delay discounting: The roles of fungibility and perishability". In: *Behavioural processes* 131 (2016), pp. 47–52.

[25] Jacob Hornik and Dan Zakay. "Psychological time: The case of time and consumer behaviour". In: *Time & Society* 5.3 (1996), pp. 385–397.

[26] Daniel Houser et al. "Temptation and Commitment in the Laboratory". In: *Games and Economic Behavior* 107 (2018), pp. 329–344.

[27] Kaitlyn Jardine. "The psychology of waiting: designing for satisfaction in emergency department waiting environments". In: (2017).

[28] Tjalling C Koopmans. "Stationary ordinal utility and impatience". In: *Econometrica: Journal of the Econometric Society* (1960), pp. 287–309.

[29] Piyush Kumar, Manohar U Kalwani, and Maqbool Dada. "The impact of waiting time guarantees on customers' waiting experiences". In: *Marketing science* 16.4 (1997), pp. 295–314.

[30] David Laibson. "Golden eggs and hyperbolic discounting". In: *The Quarterly Journal of Economics* 112.2 (1997), pp. 443–478.

[31] Kelvin Lancaster. "An axiomatic theory of consumer time preference". In: *International Economic Review* 4.2 (1963), pp. 221–231.

[32] Henry X Liu et al. "Real-time queue length estimation for congested signalized intersections". In: *Transportation research part C: emerging technologies* 17.4 (2009), pp. 412–427.

[33] George Loewenstein. "Out of control: Visceral influences on behavior". In: *Organizational behavior and human decision processes* 65.3 (1996), pp. 272–292.

[34] George Loewenstein and Drazen Prelec. "Anomalies in intertemporal choice: Evidence and an interpretation". In: *The Quarterly Journal of Economics* 107.2 (1992), pp. 573–597.

[35] Wenhong Luo et al. "Impact of process change on customer perception of waiting time: a field study". In: *Omega* 32.1 (2004), pp. 77–83.

[36] David H Maister et al. *The psychology of waiting lines*. Harvard Business School Boston, MA, 1984.

[37] Paola Manzini and Marco Mariotti. "A vague theory of choice over time". In: *Advances in Theoretical Economics* 6.1 (2006), pp. 1–27.

[38] Samuel M McClure et al. "Separate neural systems value immediate and delayed monetary rewards". In: *Science* 306.5695 (2004), pp. 503–507.

[39] Samuel M McClure et al. "Time discounting for primary rewards". In: *Journal of neuroscience* 27.21 (2007), pp. 5796–5804.

[40] John A Michon. "The compleat time experiencer". In: *Time, mind, and behavior*. Springer, 1985, pp. 20–52.

[41] Walter Mischel and Ralph Metzner. "Preference for delayed reward as a function of age, intelligence, and length of delay interval." In: *The Journal of Abnormal and Social Psychology* 64.6 (1962), p. 425.

[42] D Norman. "Sociable design". In: *Journal, http://www. jnd. org/dn. mss/sociable_design_intr. html* (2008).

[43] Edmund S Phelps and Robert A Pollak. "On second-best national saving and game-equilibrium growth". In: *The Review of Economic Studies* 35.2 (1968), pp. 185–199.

[44] Daniel Read. "Is time-discounting hyperbolic or subadditive?" In: *Journal of risk and uncertainty* 23.1 (2001), pp. 5–32.

[45] Derek D Reed and Brian K Martens. "Temporal discounting predicts student responsiveness to exchange delays in a classroom token system". In: *Journal of Applied Behavior Analysis* 44.1 (2011), pp. 1–18.

[46] Paul A Samuelson. "A note on measurement of utility". In: *The review of economic studies* 4.2 (1937), pp. 155–161.

[47] Marc Scholten and Daniel Read. "The psychology of intertemporal tradeoffs." In: *Psychological review* 117.3 (2010), p. 925.

[48] Edith Shalev and Vicki G Morwitz. "Does time fly when you're counting down? The effect of counting direction on subjective time judgment". In: *Journal of Consumer Psychology* 23.2 (2013), pp. 220–227.

[49] Madalina Sucala, Bari Scheckner, and Daniel David. "Psychological time: interval length judgments and subjective passage of time judgments". In: *Current psychology letters. Behaviour, brain & cognition* 26.2, 2010 (2011).

[50] Richard Thaler. "Some empirical evidence on dynamic inconsistency". In: *Economics letters* 8.3 (1981), pp. 201–207.

[51] Ewart AC Thomas and Nancy E Cantor. "On the duality of simultaneous time and size perception". In: *Perception & Psychophysics* 18.1 (1975), pp. 44–48.

[52] Michel Treisman. "Temporal discrimination and the indifference interval: Implications for a model of the" internal clock"." In: *Psychological Monographs: General and Applied* 77.13 (1963), p. 1.

[53] EM Wölbert and Arno Riedl. *Measuring time and risk preferences: Reliability, stability, domain specificity*. Tech. rep. Maastricht University, Graduate School of Business and Economics (GSBE), 2013.

[54] Jiao Rong Wu, Su Gang Lu, and Ying En Ge. “Identifying factors impacting customersâ perceived waiting time in high density passenger flow waiting areas”. In: *Procedia-Social and Behavioral Sciences* 96 (2013), pp. 1801–1811.

[55] Dan Zakay. “Subjective time and attentional resource allocation: An integrated model of time estimation”. In: *Advances in psychology*. Vol. 59. Elsevier, 1989, pp. 365–397.

[56] Dan Zakay and Richard A Block. “Temporal cognition”. In: *Current directions in psychological science* 6.1 (1997), pp. 12–16.

Appendix: Experimental Materials

Instruction Sheet to Subjects

Instructions to Participants.

Thank you for agreeing to participate in today's experiment. This is an experiment in decision making over time and over money. Depending on the decisions you make, you will be able to earn money that will be paid to you as you leave. **Once the experiment has started, we ask that you refrain from speaking to any other participants in the room.**

Your decisions. The questions you will be asked today is of the following structure. We want you to indicate the amount of money, if paid to you now, would make you indifferent between that amount of money now and a fixed amount of money paid in the future.

- For example, let's assume we are offering you € 10 tomorrow. We want you to tell us what is the smallest amount of money, that would be paid to you now, that would make you indifferent between getting that amount now and the € (10) tomorrow. This means you are equally satisfied if we give you the € (10) tomorrow or if we gave you the amount X you told us now: you don't care which happens.
- We call this amount X the **indifference amount**!

The questionnaire. In order to find out your indifference amount, we will ask a number of questions.

- For each question, you will be told that we are willing to offer you a certain amount of money M with some delay T.
- Then we will ask you to tell us what amount X would make you indifferent between X today and M with some delay T.
- There are 30 questions for you to answer because we want to find out your indifference amount X for different offers M and for different delays in time T.

How will we pay you? Once you have answered all 30 questions, the computer will randomly choose one of the 30 questions to implement in real life. This means that any one of the 30 questions has an equal chance of being chosen to happen, and you will be paid according to what you answered for them.

- Once a question is randomly chosen, we have information about your indifference value X for a specific offer M with a delay T
- The computer will draw a random number R between 0 and M to offer you now.
- Then two things can possibly happen:
  - either the new offer R is higher than your indifference value X, and you get the new offer R now and nothing next week;

- or the new offer R is lower than your indifference value X, and you get nothing now and M with a delay T

- If you have to wait, you will be asked to wait in the test center for the duration T.
- Either way, know that with the procedures we have in place, it is in your best interests, in terms of getting the best payoff, to report the indifference amount truthfully. Telling us anything else will reduce your chances of getting the best payoff!

An example. Just to give you a better illustration of what will happen today in the lab:

- Let's say you have answered all the questions and the question that was drawn is the following:

  What amount of money € x, if paid to you now, would make you indifferent to € 10 paid to you in an hour?

- Let's assume you answered € 6. This is the X. That means you don't care which of the following happens: either you get paid € 6 today or € 10 in 3 hours. Here M is 10 and T is 1 hour.
- So, the computer will draw a random number between 0 and 10. This means any number 2, 5 or 8 all have an equal chance of being drawn.
- Let's say 8 is drawn: since 8 is larger than 6, your indifference amount, you will get € 8 now, and nothing in an hour. You may then leave immediately.
- Let's say instead that 2 is drawn: since 2 is smaller than 6, your indifference amount, you will get nothing now and the original offer of € 10 in an hour. You will be allowed to leave after an hour.
- Notice that either way, you will be leaving here with some money! As mentioned, to maximise the amount of money you leave here with, you should tell us your true indifference value!
- The money will be made available to you in cash at the appropriate delay.

Before we begin. We ask that you keep all your personal belongings, including your phone, your wallet and other valuables in the holding room. Rest assured that we will keep an eye on your belongings. As you enter the experimental laboratory, please note that it is a total silence zone. If you have any questions about the set-up, please address them to the experimenters now.

Final Reminder. Please refrain from communicating with any other participants or from making noises that might distract other participants.

Thank you and good luck!

Proposed Screen Captures

The following figures are screen captures of the experimental design the participants will see on their computers.

- Screens A1 to A4 correspond to the waiting screen, each with the specific framing of the waiting time.
- Screen A5 is a transition screen.
- Screen A6 is a random example of a question, the number 21 is irrelevant here.
- Screen A7 is another transition screen to the payout phase, with the random question drawn.
- Screen A8 and A9 is one example of a BDM draw with a draw value higher than the indifference value of the drawn question.
- Screen A10 and A11 is the opposite example of a BDM draw with a draw value lower than the indifference value of the drawn question.

Figure 2: **Screen A1**: Waiting Screen for the treatment group with No Information (NI)

Figure 3: **Screen A2**: Waiting Screen for the treatment group with Information about the duration (I)

Figure 4: **Screen A3**: Waiting Screen for the treatment group with Information about the duration and a countup clock (CU)

Figure 5: **Screen A4**: Waiting Screen for the treatment group with Information about the duration and a countdown clock (CD)

Figure 6: **Screen A5**: Transition screen from the waiting phase to the questionnaire phase, for all treatment groups

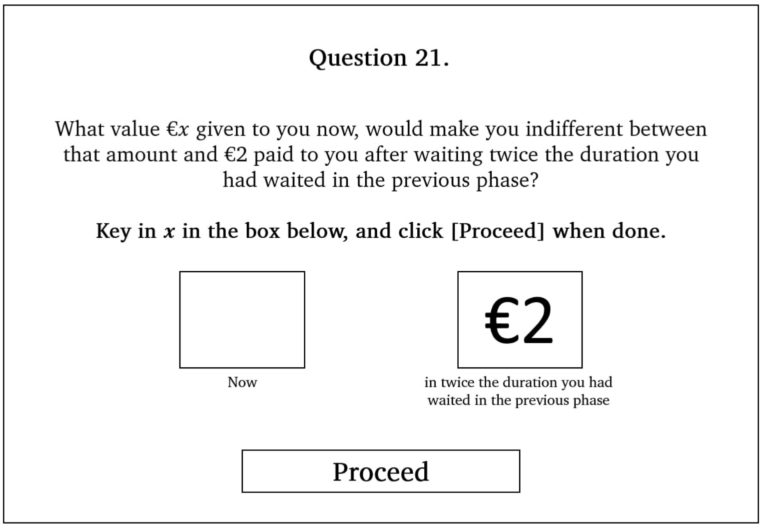

Figure 7: **Screen A6**: An example question

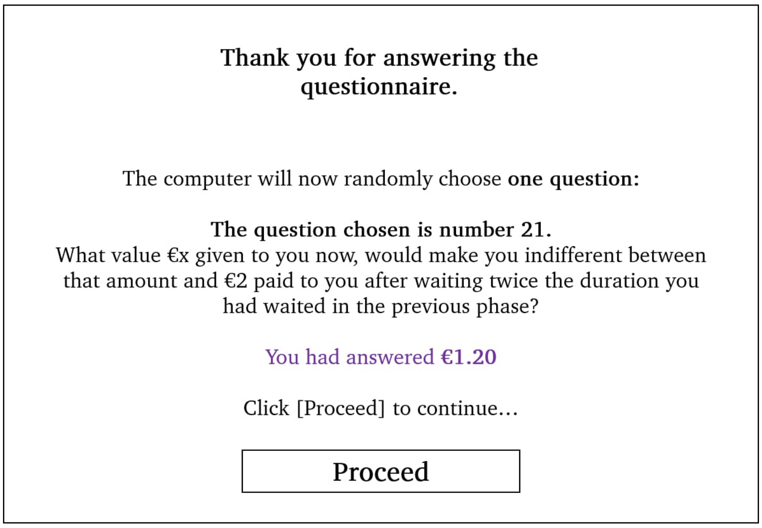

Figure 8: **Screen A7**: Transition screen to payoff with random question draw

Figure 9: **Screen A8**: BDM draw of random number + conclusion of payout now

Figure 10: **Screen A9**: Notification of current payout

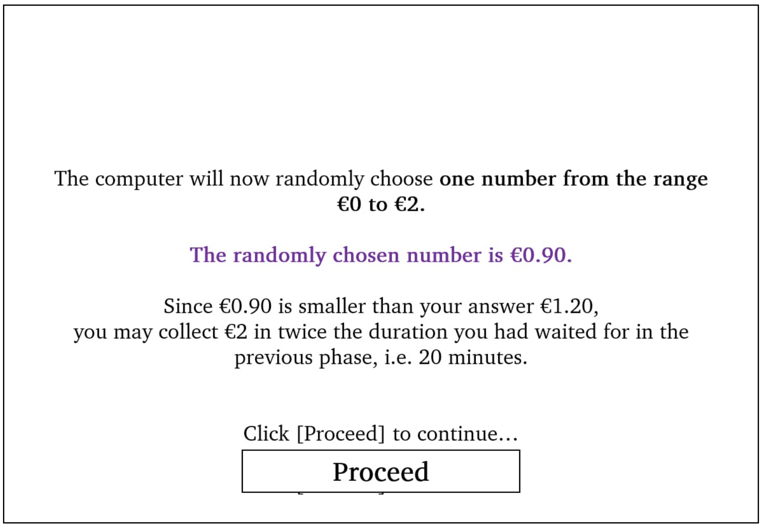

Figure 11: **Screen A10**: BDM draw of random number + conclusion of future payout

Thank you for participating.

The 20 minutes is now over. You are now are eligible for the €2 reward now and your experiment is now finished. Upon finishing, please proceed to the experimenter's room to collect your reward.

Click [Exit] to complete the experiment.

Exit

Figure 12: **Screen A11**: Notification of future payout