Self Control and Intertemporal Choice: Evidence from Glucose and Depletion Interventions*

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Abstract

Recent economic theories model intertemporal choice as a problem of willpower or self control, *i.e.* of restraining a natural impulse to consume today. We use two interventions that have been shown by psychologists to affect self-control to examine whether this applies to the intertemporal savings decision, as measured in a laboratory elicitation of time preference. Contrary to the predictions of willpower-based models, we find that prior participation in an impulse-controlling activity ("depletion") increases savings. Consistent with those models, sugared-drink consumption raises savings relative to a sugar-free placebo, but the placebo drink also raises savings (relative to no drink) by about the same amount. All these treatment effects are driven by increases in the intertemporal substitution elasticity and are much stronger among subjects with average (as opposed to high) cognitive ability. Overall, we suspect that factors like subjects' attention to the details of the decision are affected by our interventions and are more relevant to the financial decisions we model than are differences in willpower and body-energy budgets.

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1 Introduction

Models of willpower, temptation and self-control are now commonplace in economics. They all aim to capture the visceral push-pull relationship between temptation and prudence that seems a natural way to conceptualize intertemporal choices. Decision makers are modeled as two conflicting selves (Shefrin and Thaler 1988; Bernheim and Rangel 2004; Fudenberg and Levine 2006) or as receiving extra utility when gratification is immediate (Laibson 1997; O'Donoghue and Rabin 1999). Ozdenoren *et al.* (2012) explicitly model willpower as a depletable resource. But how relevant is this modeling approach to fundamental economic behaviors such as borrowing and saving money? By implementing interventions identified by the psychology literature as shifters of willpower, our goal in this paper is to determine whether a willpower-based theoretical paradigm is consistent with across-treatment comparative statics in an abstract borrowing/saving environment.

Psychological research suggests that willpower –the ability to control the self and refrain from impulsive or short-sighted decisions– is negatively affected by prior performance of a task that also requires impulse control. Both dieters who are exposed to the sight of tempting snacks, and those who are asked to suppress their emotional responses while watching an emotional video, subsequently consume more ice cream than dieters engaged in tasks not requiring impulse control (Vohs and Heatherton 2000).[1] Similar effects have been found for performance on a wide variety of tasks.[2] Muraven and Baumeister (2000) argue that these results are consistent with a resource-depletion model of self-control: " controlling one's own behavior requires the expenditure of some inner, limited resource that is depleted afterward." (p.247).

More recently, a number of investigators have argued that blood glucose –which constitutes the body's primary source of energy– is the limited resource that is depleted by acts of self-regulation. In a series of experiments, Gailliot *et al.* (2007, 2009) find that engaging in self-control reduces measured levels of blood glucose, that these induced low glucose levels predict poor performance

[1] Similar studies of the effects of willpower depletion –manipulated in a variety of ways– on subjects' management of food and alcohol consumption include Kahan *et al.* (2003), Muraven *et al.* (2005) and Baumeister *et al.* (1998).

[2] These include resisting opportunities to cheat the experimenter for financial gain (Mead *et al.* 2009), suppressing stereotypes and prejudice (Gordijn *et al.* 2004; Richeson and Shelton, 2003; Richeson and Trawalter, 2005; Richeson *et al.*, 2005), restraining aggression (DeWall *et al. 2007*; Stucke and Baumeister, 2006) and impulsive discounting (Hinson *et al.*, 2003). In economics, Bucciol *et al.* (2011) demonstrated that productivity in a task is negatively affected by prior exposure to consumption temptation while Burger, Charness and Lynham (2011) showed that a depleting task –the Stroop (1935) task– improves long-run task completion in a procrastination study.

on a variety of subsequent self-control tasks, and that consumption of a drink sweetened with sucrose (relative to an artificially-sweetened drink) mitigates these poor performance levels.[3] Effects of sucrose consumption have been demonstrated on outcomes including inflicting pain on others, the use of racial stereotypes and slurs, and support for social welfare.[4]

Motivated by the parallels between the psychology experiments and economic theory, this paper considers whether depletion of impulse control and sucrose consumption affect a fundamental aspect of economic behavior: the allocation of income over time. While it might be tempting to view intertemporal allocation decisions as simply a case of resisting an impulse to consume more sooner, it is not at all clear that factors that affect actions like using racial stereotypes or inflicting pain on others will affect financial decisions at all, or in the same way. Adapting the Convex Time Budget technique developed by Andreoni and Sprenger (2012), we allow participants in a laboratory experiment to make a series of choices about payments they will receive sooner or later, across conditions related to willpower depletion and sugar consumption.

In addition to testing a fundamental prediction of willpower-based models of time preferences, our paper makes the following contributions. First, by exposing subjects to a menu of intertemporal choices, we are able to formalize the somewhat imprecise concept of willpower by distinguishing three ways an intervention can affect intertemporal choices: (i) raising the desire to have money sooner rather than later, regardless of whether 'sooner' is today; (ii) raising the desire to have money today, compared to all other options; or (iii) reducing subjects' willingness to sacrifice earlier consumption when its relative cost rises. Loosely, these three effects map into the parameters of a widely used intertemporal utility function –the discount rate, present bias and intertemporal elasticity of substitution– which we structurally estimate for each subject in our sample.[5] Of these,

[3]When sucrose is consumed, glucose is absorbed into the bloodstream at a rate of 30 calories per minute. Metabolization to the brain typically occurs within ten minutes (Donohoe and Benton 1999).

[4]See Aarøe and Bang Petersen (2013) on social welfare and Gailliot and Baumeister (2007) for a review of studies in psychology. The role of nutrition has been little studied in economics. Dotter (2013) has found an impact of breakfast programs in schools on both math and reading scores. While well-being is improved by the consumption of fruits and vegetables (Blanchflower *et al.* 2012), productivity has been shown to increase after individuals were provided chocolates and fruits (Oswald *et al.* 2014). Finally, absorbing glucose seems to impact the mode of reasoning of individuals, and notably increases the likelihood of Bayesian choices over reinforcement heuristic-based choices (Dickinson *et al.* 2013).

[5]Our experiment is one of very few that is designed explicitly to examine treatment effects on the parameters of structural model. Callen *et al.* (2013) and Carvalho *et al.* (2013) do so with risk preferences and violent trauma and time preferences and savings accounts respectively. This technique can provide a deeper understanding of the treatment effects and allows for more flexible policy analysis.

the informal 'willpower' hypothesis probably maps most closely into the present bias parameter (ii). Some alternative cognitive factors, such as, for example, the care or attention subjects are applying to their decisions, may map more closely into the price-sensitivity parameter (iii).

Second, motivated by the literature on cognitive ability and time preferences we explore the interaction between our treatment effects and cognitive ability. Previous literature has identified strong correlations between childrens' ability to resist temptation in the famous marshmallow experiment (Mischel, Ebbesen and Raskoff Zeiss 1972) and a variety of cognitive outcomes, including SAT scores (Shoda *et al.*, 1990), IQ (Funder and Block 1989) and college GPA (Kirby *et al.*, 2005).[6] A notable recent finding is that of Benjamin *et al.* (2014), who identify a relationship between cognitive ability and 'behavioral' risk preferences. Both their work and ours contribute to the broader literature studying *which* individuals violate the standard assumptions of economic models, and *when* they do so. In this regard, we generate estimates (from the bottom half of our sample) that are representative of the 50th-90th percentiles of French high school graduates, and we compare the behavior of this group to a very high-ability group (the top half of our sample, which corresponds to the top 10% of high school graduates).

Finally, our study contributes to a recent literature on the impact of temporary manipulations of the decision environment on time preferences. In particular, Ifcher and Zarghamee (2011) find that induced positive affect leads to more patient choices between money received today vs. later.[7] With a within-subject design, Wang and Dvorak (2010) find that sucrose consumption raises patience whereas drinking a sugar-free beverage decreases patience.[8] The key differences between our paper and these two studies are our study of a willpower-depleting intervention and our use of a time-preference task and structural estimation procedure that allow us to distinguish treatment effects on discounting, present bias and price-sensitivity.[9] Together, these aspects of our approach

[6]Other studies that have linked intelligence with discounting include Frederick (2005), Dohmen *et al.* (2010), Rustichini *et el.* (2012) and Shamosh and Gray's (2008) meta-analysis.

[7]Other manipulations include stress. While Haushofer *et al.* (2013) find no effect of stress induction on patience, Cornelisse *et al.* (2013) find that directly administering the stress hormone, cortisol, *does* make people more present-biased. Using binary choices, none of these studies can estimate the structural model of preferences presented here.

[8]To explain the patience-enhancing effects of sucrose consumption, Wang and Dvorak propose an energy-budget regulation model, in which a high body energy budget makes organisms more future-oriented to facilitate reproduction. In contrast, they argue that the artificial sweetener alerts the body to a caloric crisis, signaling a low energy budget, which leads to more present-oriented choices.

[9]Wang and Dvorak estimate time preferences by imposing a one-parameter hyperbolic utility function on each subject. A subject's preference parameter (k) is elicited by giving them seven choices between money 'tomorrow' and a future date, with each choice corresponding to indifference at a different level of k. The subject's k is then

shed light on the mechanisms behind all our treatment effects.

We find that time preferences are sensitive to all our interventions, but we do not find that willpower depletion makes our subjects less patient.[10] Instead, participants who have been exposed to a widely-used willpower-depleting task –the Stroop (1935) test– exhibit *increased* patience in the subsequent time preference elicitation. Consistent with previous studies of impulse control in other contexts, we find that relative to a sugar-free beverage, consumption of a sugared beverage increases patience in our time preference task. Surprisingly, however, this effect is generally smaller in magnitude than the patience-increasing effect of the sugar-free beverage itself (compared to a baseline condition with no beverage), casting doubt on the importance of body-energy budgets relative to situational factors. That said, all our estimated treatment effects are economically significant in magnitude, corresponding to large differences in demand for short-term loans.

Consistent with many studies showing an interaction between cognitive ability and time preferences, we find that all our treatment effects are stronger in the bottom half of our sample, when ranked by cognitive ability. Subjects with very high cognitive abilities, on the other hand, make decisions that for the most part are unaffected by our attempts to manipulate their willpower. Finally, both our nonstructural and structural estimates indicate that the main utility parameter affected by the treatments (whether depletion, sugared drink or placebo drink) is not the subjective discount rate or present bias parameter, but the intertemporal elasticity of substitution. While subjects in all treatments choose the same level of early income when early income is cheap, treated subjects are much more likely to reduce their early income when its relative price rises.

What processes might explain the tendency of our subjects –excluding those with very high cognitive abilities– to become more price-sensitive in their intertemporal choices when exposed to all our experimental treatments? While we did not set out to test attention-based models of intertemporal choice (such as Koszegi and Szeidl 2013), we note that the effects of all our treatments

calculated as the geometric midpoint between the k's of the two options where their choice switches between the early and late option. Since the actual choice options facing subjects before and after beverage consumption were different, this procedure relies heavily on the assumption of a specific one-parameter family of preferences. Also, neither Wang-Dvorak nor Ifcher-Zarghamee gave subjects the choice between consumption at two future dates, so they cannot distinguish discounting from present bias.

[10]Throughout this paper we use 'patience' as convenient shorthand for a tendency to delay the receipt of income, holding other conditions (prices, amount of delay), constant. Since 'patience' is sometimes also used, more specifically, to refer to an absence of present bias in a structural model of choice, we will be explicit whenever we discuss present bias per se.

on subjects' price sensitivity are consistent with attention-enhancing effects.[11] Viewed this way, our estimated treatment effects suggest that exposure to the Stroop test may paradoxically have primed our subjects to pay more attention to the time preference task. Similarly, both the sugared and the placebo beverages may have improved our fasted participants' ability to concentrate on the task, though the effect of the placebo beverage casts doubt on blood glucose *per se* as the primary mechanism for this effect.

Also consistent with an attention-based explanation, we note that –like all experimental elicitations of time preferences– our procedures elicit preferences for the timing of income, not consumption.[12] Thus, as is well known (see Chabris, Laibson and Schuldt 2008), experimental estimates of intertemporal substitution elasticities which are substantially below infinity imply either that subjects do not have low-cost access to capital markets, or fail to perceive those extra-laboratory options for shifting income over time. Bearing this in mind, estimates of our price-sensitivity parameter may also reflect changes in subjects' awareness of those options. To the extent that cognitively better-endowed persons have a greater tacit understanding of these credit market arbitrage opportunities, this interpretation is also consistent with the fact that our treatment effects largely vanish among higher-scoring subjects.

The remainder of this paper is organized as follows. Section 2 details the experimental design. We present our data analysis in Section 3 while Section 4 discusses our results and concludes.

2 The Experiment

2.1 Treatments

Our experiment consists of three types of sessions: Baseline, Depletion and Drink. Within each session type, there are five distinct parts, the orders of which change across session type. In a Drink session, the phases are: (1) consumption of drink and entry questions, (2) rest to allow any

[11] One recent study suggesting that attention is a key factor in decision quality is Carroll *et al.* (2009) show that simply manipulating the default savings plan is a powerful tool for increasing individual savings. They also find that forcing an active choice improves choices. In addition, neuroeconomic studies have demonstrated that attention manipulation can improve decision-making in situations involving self-control (Hare *et al.* 2011, Harris *et al.* 2013).

[12] Augenblick *et al.* (2012), study the allocation of effort over time. Consistent with the notion that intertemporal arbitrage opportunities are lower for effort than income, they find substantially more evidence of present bias than we do here.

Table 1: Experimental Design

Treatment	***Task***				
	(1)	(2)	(3)	(4)	(5)
Baseline	Entry survey	Rest	Time preference task	Stroop task	Exit survey
Depletion	Entry survey	Rest	Stroop task	Time preference task	Exit survey
Placebo	Sugar-free drink & Entry survey	Rest	Time preference task	Stroop task	Exit survey
Sugar	Sugared drink & Entry survey	Rest	Time preference task	Stroop task	Exit survey

sucrose in the drink to be metabolized into blood glucose, (3) elicitation of time preferences, (4) depletion of self-control in the Stroop test, and (5) an exit survey that includes Frederick's (2005) Cognitive Reflection Test (CRT). The structure of the Baseline sessions is similar to that of Drink sessions, except that no beverage is given. In Depletion sessions, we invert the order between the Stroop test and the elicitation of time preferences. Finally, within the Drink sessions, we have two conditions corresponding to a drink containing sugar or a sugar-substitute. These variations give us four treatments: Baseline, Depletion, Placebo and Sugar. Table 1 lays out the progression of the experiment for each treatment.

The comparison between the Depletion treatment and the Baseline allows us to determine whether performing an initial task that requires impulse control affects the decision to defer income in the time preference task. The comparison between the Sugar treatment and the Placebo treatment allows us to study whether the consumption of sugar affects time preferences. Finally, if time preferences react to the consumption and metabolization of sucrose rather than the drink itself, we expect to observe no differences in choices when comparing the Placebo treatment and the Baseline. We discuss each task and drink consumption in more detail below.

2.2 Time Preference Elicitation

To elicit time preferences, we implement the Convex Time Budget (CTB) method of Andreoni and Sprenger (2012, henceforth AS). This approach allows us to estimate individual-specific preference parameters.

In every choice, participants received a budget of 16 tokens to allocate between an early payment, c_t, and a late payment, c_{t+k}, with t the early payment date and k the delay between the two dates. Participants made 45 allocation decisions and one of these decisions was randomly selected at the end of the session for actual payment according to the allocation of tokens between the two dates. The 45 budgets combine three early payment dates (t = 0, 5, 15 weeks), three delay lengths (k = 5, 10, 15 weeks) and various price ratios. Thus, there were only seven paydays evenly spaced at five weeks intervals (0, 5, 10, 15, 20, 25, 30 weeks). For each (t, k) combination, participants had to make five decisions involving various interest rates. We defined three rate progressions that were combined with the various early payment dates while the combination of budget progressions and delay lengths were kept constant. The value of a token at the late date, a_{t+k}, was always equal to €1, while the value of the token at the early date, a_t, varied between a minimum of €0.67 and a maximum of €0.99. Allocating all the tokens to the late payment date paid €16; allocating all the tokens to the early payment date paid a minimum of €10.72 and a maximum of €15.84. The progressions were defined in order to offer implied annual interest rates, compounded quarterly, between 4% and 845%. Table A1 in the Appendix presents all the choice sets.

The presentation of the 45 decisions was very similar to that in AS. A choice screen had nine decision tabs that were displayed successively and corresponded to the nine (t, k) combinations. The order between the nine tabs was randomly and independently determined for each participant to control for order effects. Each decision tab displayed five budget decisions presented in order of increasing gross interest rate. To facilitate decision-making by a better visualization of delays, each decision tab displayed a dynamic calendar highlighting the current date, the early date and the late date in different colors. It also displayed the values of a token at the early date and at the late date, together with the values in Euros of the earnings corresponding to the decisions. A sample decision tab is reproduced in the Appendix. The boxes for entering the allocation decisions were initially blank. As soon as a value was entered either for the early date or the late date, the other box was filled automatically to ensure that the total budget was 16 tokens and the corresponding payoffs in Euro at the two dates were also displayed.

This design allows us to estimate for each individual her discount rate, the curvature of her utility function (through the variations of k and of the gross interest rate), and her present bias (through the variation of t). In the context of our study, it allows us to examine which, if any, of these dimensions is impacted by self-control depletion and sucrose consumption.

2.3 Willpower Depletion

We used a Stroop test (Stroop, 1935) to deplete self-control as shown by many studies in social psychology (for a survey of the test, see MacLeod 1991). In a typical Stroop test, individuals have to read the color of ink used to write words independently of the color names of words. In some trials, there is congruence between the color of the word and the color of the ink (the word "yellow" is written in yellow) but in other trials there is no congruence (the word "yellow" is written in red and the correct answer is red). The incongruent stimuli typically require more time and produce more mistakes than the congruent stimuli because the brain automatically decodes the semantic meaning of the word and needs to override its first reaction to identify the color of the ink. Shortcutting the automatic process requires self-control.[13]

In our experiment, the participants' computer screen displayed a series of color words (black, blue, yellow, green and red) successively, and the participants were instructed to indicate, as quickly and accurately as possible, the ink color in which the word was written. The list of possible colors was displayed at the bottom of the screen and the participants had to press the button corresponding to the color of the ink, whether or not that matched the color name of the word (see instructions in Appendix). They had to complete congruent and incongruent Stroop trials in random order for 6 minutes. On average they completed 126 trials (S.D. = 11.69). As expected, the time spent on incongruent words was significantly higher than on the congruent words (two-tailed t-test, $p < 0.001$).

2.4 Drink Consumption

Following Gailliot *et al.* (2007), participants in each Drink session were given 14 ounces (40 centiliters) of a soft drink sweetened either with sugar or with a sugar substitute. Both types of drinks had the same appearance. The sugared drink contained 158 kilocalories and the placebo

[13] Note that poor performance in the difficult trials of the Stroop test has been linked to low glucose level (Benton *et al.*, 1994). Study 5 in Gailliot *et al.* (2007) also shows that a lower level of glucose after performing the Stroop test impaired persistence in an additional task. The studies on self-control by Gailliot *et al.* do not only use the Stroop test but they indicate that it is one of the most frequently used measures of self-control.

drink contained 10.[14] We used a double blind procedure to administer the drinks: neither the participants nor the experimenters were aware of the sugar content of the beverage.

After being invited to drink the beverage, participants could rest in silence and read magazines that we distributed during 10 minutes in order to allow the sucrose to be metabolized into glucose. Three minutes before the end of this period, participants had to assess the beverage and to report their usual consumption of soft drinks.[15] In the Baseline and the Depletion treatments, the same rest period of 10 minutes was implemented.

2.5 Procedures

The experiment was computerized, using the REGATE-NG software. It consisted of 8 sessions conducted at the laboratory of the GATE (Groupe d'Analyse et de Théorie Economique) institute in Lyon, France. Undergraduate students from the local engineering and business schools were invited via the ORSEE software (Greiner 2004). Between 17 and 20 participants took part in each session, for a total of 149 participants. Two sessions of the Baseline treatment were implemented with a total of 34 participants; two sessions of the Depletion treatment were implemented involving 40 participants; and four Drink sessions were implemented with 75 participants (37 in the sugar condition and 38 in the placebo condition).

The invitation message addressed to the participants of all treatments indicated that they may possibly have to drink a beverage containing sugar during the session and that individuals suffering or thinking that they may suffer from a pathology linked to blood glucose regulation (like diabetes) should abstain from participating. After signing up, all the participants in all the treatments were instructed not to drink or eat at least three hours prior to the beginning of the session in order to stabilize blood glucose levels. Upon arrival we recorded the time of their last intake. Since chronobiology may influence economic decision-making, all the sessions were run at noon, when

[14]Specifically, the drinks were Fanta "Citron frappe" and Fanta Zero "Citron frappe". They were dispensed in glasses (not the original container) and appear identical (see Figure A1 in the Appendix). Neither contains caffeine, though both contain ascorbic acid (vitamin C).

[15]The questions were: 1) Please rate your enjoyment of the beverage you just consumed, between 1 and 10. 2) How many calories do you think the beverage contained? 3) How often do you drink soft drinks (Coke, Pepsi, lemonade, ...): every day / every week / once or twice a month or less / less than twice a month? Although participants in the Placebo condition assessed the beverage less positively (mean = 4.55, S.D. = 2.77) than those in the Sugar condition (mean = 5.57, S.D. = 2.58) (two-tailed Mann-Whitney test, $p = 0.097$), they did not realize that they received a placebo. Indeed, they predicted the same number of calories contained in the beverage (mean = 124.16, S.D. = 86.26) than the participants placed in the Sugar condition (mean = 140.41, S.D. = 98.26) ($p = 0.497$).

the level of blood glucose is low.[16]

Upon arrival, the participants had to sign a consent form reminding them that they should not participate if they suffer from a disease related to failure of blood sugar regulation. Then participants randomly drew a tag from a bag assigning them to a terminal. The instructions for each segment were distributed and read aloud by the experimenter after the completion of the prior segment (see Appendix).

The elicitation of time preferences requires very strict procedural rules. To participate in the experiment, the students were required to own a personal bank account and were informed by the invitation message that they would be paid by a wire transfer to their bank account; a bank statement was required.[17] During the session, instructions informed the participants that a show-up fee of €5 would be wired to their bank account in addition to their other payoffs at two different dates, regardless of their decisions: half of the show-up fee amount would be paid at the early date and the other half at the late date indicated by the decision randomly selected at the end of the session for payment. The show-up fee had no differential influence on the 45 allocation decisions. Participants were also informed that the dates mentioned on the decision screens were the dates at which the wire transfers would be ordered by the finance department.[18] To maximize the confidence of the participants about the payment of their earnings, they received a document stating that the bank transfer would be ordered by the National Center for Scientific Research (CNRS).[19] In addition, the document mentioned the name, email address and phone number of the professor in charge of the experiment who could be contacted in case of any problem with the payment.

At the end of each session, participants received a feedback on the decision randomly selected

[16]We did not measure baseline blood glucose levels, which would have required taking blood samples.

[17]We cannot rule out that the information given in the message (payment wired to the bank account and possibility of having to drink a beverage) has led to a self-selection of participants. However, the sessions were booked as quickly as usual. In addition, we asked 44 students participating in another experiment with standard cash payment whether they owned a personal bank account; all of them answered positively. Moreover, there is no reason to believe that the two criteria for participating were correlated. Finally, the message did not mention that the payment could be made at two different dates.

[18]The administration committed to respect exactly the dates of the transfers and sent us a feedback after each payment. We believe the transaction costs associated with this payment methodology are lower than the typical approach used in this type of experiment, which relies on personal checks or vouchers.

[19]In France, CNRS is a well-known science and technology public agency. It employs 25,000 people and it operates through 1,235 research institutes. Students are aware that the GATE institute is operated by both the CNRS and the University of Lyon.

for payment, indicating their payoffs and the dates of the two wire transfers for this decision. Then, they had to complete an exit survey which included questions about their demographics and average mark on the final high school exam (Baccalauréat). Sessions lasted 60 minutes and participants averaged earnings of 20.43 ($26.62, with a standard deviation of €0.97 ($1.26), including the show up fee.

3 Results

We present our results in four sections. The first section establishes a number of basic patterns in a pooled sample of all treatments, to provide context for the study of treatment effects. The second and third sections are nonparametric and structural approaches to analyzing the treatment effects, respectively. The final section presents some robustness checks. Since -as noted– one of our central questions is how the impact of treatment manipulation on patience is mediated by the subjects' cognitive ability, we present all of our experimental results separately according to our subjects' reported achievement on the French Baccalauréat exam.[20] We divide our participants in half relative to the median score in our sample, which was 16; this is also an important cutoff in the distribution of scores for student achievement.[21] Importantly, because only 9% of French Baccalauréat recipients earned a score of 16 or higher (our participants are drawn from selective universities), we refer to our two groups as "high score" and "lower score" respectively. Our high-scoring subjects clearly represent an elite level (about the top decile) of achievement among French high school graduates, while our lower-scoring group roughly represents the 50th through 90th percentiles. Thus the results for our lower-scoring group are more representative of a typical high school graduate in France, and we focus much of our discussion on that group.[22]

[20] The French Baccalauréat exam is taken at the end of high school (*lycée*). In 2012, slightly over three quarters of French youth had passed the Baccalauréat.

[21] We also consider fuller distributional effects and effects based on lab-elicited CRT score.

[22] The results of the Cognitive Reflection Test (CRT) performed at the end of the sessions are highly correlated with the Baccalauréat score, and we can replicate our main results using this measure of cognitive ability as well. However since subjects' CRT results could be affected by our treatments, we focus on the Baccalauréat-score based results.

3.1 Overall Features of Behavior

We start by presenting two foundational results that verify aspects of our model and design, plus some simple descriptive statistics for the pooled sample across all treatments. The first result is that subjects' aggregate demand curves in the experiment satisfy two general predictions of utility-maximizing intertemporal behavior.

Result 1 - Consistent with predictions for agents who discount the future and have some preference curvature, mean demand for early income exceeds half the 16-token endowment at interest rates near zero, then declines monotonically with the price of early income. This behavior characterizes both high- and lower-score participants.

A simple but general model of choice between early and late tokens for any combination of early payment date (t) and delay (k) supposes that subjects solve

$$\max_{X,Y} \quad U(X) + \lambda U(Y), \quad \text{subject to} \quad RX + Y \leq M \tag{1}$$

where X is experimental income received in the early period, Y is experimental income received in the later period, $U' > 0$, $U'' < 0$, R is the price of sooner income, and M is the endowment. In (1), $\lambda < 1$ can depend on both t and k to incorporate both discounting and present bias, but is fixed within any (t, k) cell. R, on the other hand, varies within a (t, k) cell as we experimentally manipulate the implied interest rate. For this model of preferences, Figure 1 illustrates (a) that subjects should consume more than half their endowment in the early period ($X > 8$) when $R = 1$ because $\lambda < 1$, and that X should fall monotonically as R rises because income and substitution effects reinforce each other when the endowment is all in the later period, as is the case in our experiment.[23]

Figure 2 plots the data-generated demand curves for the early payment (X), separately by score

[23] Alert readers will note that equation (1) models demand for early versus late experimental *payments* in the same way economists typically model intertemporal *consumption* choices. Of course, if subjects choose total consumption according to (1) but have access to perfect capital markets, their demand for experimental payments will consist of corner solutions (i.e. either $X = 0$ or $Y = 0$) that maximize the market value of experimental payments. Effectively, subjects would behave as if the U function had little or no curvature. We test this idea formally in Section 3.3 and argue that it may shed some light on the possible mechanisms behind our estimated treatment effects.

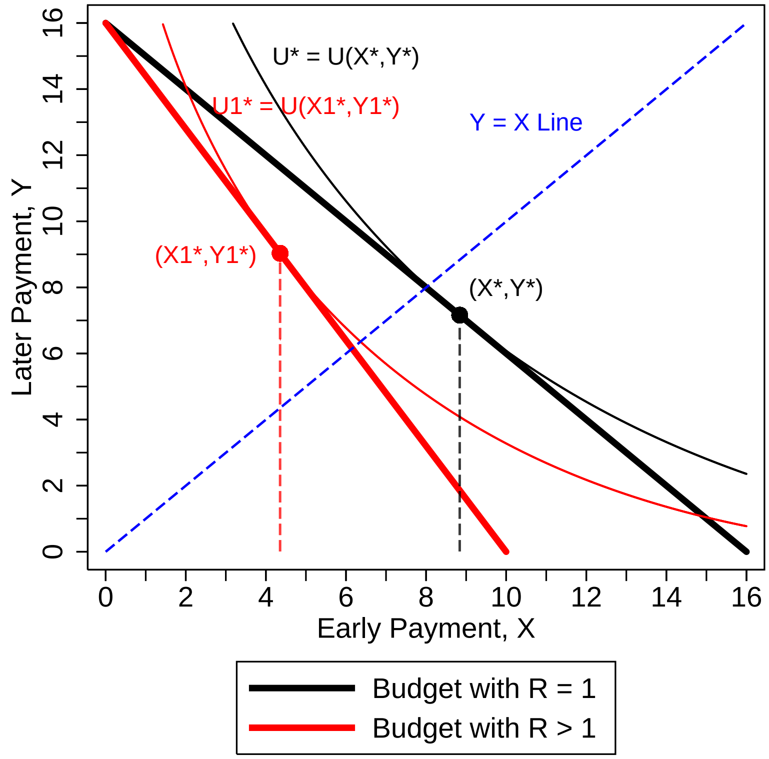

Figure 1: Predicted Behavior

and pooled across all treatments. With the exception of the shortest delay length and latest start date for both groups, the demand curves all start at above eight units of X at levels of R closest to one, then fall monotonically as R rises.[24] The success of these basic predictions suggests that our participants' choices are informative for the preferences we wish to study.

Result 2 - There is evidence of small but significant present bias in our data, among both high- and lower-test score participants.

Participants receive the first of their two payments either on the day of the experiment, 5 weeks after the experiment or 15 weeks after the experiment. To test formally for present bias we regress early payments on dummy variables for t = 5 and t = 15 as well as the price ratio while clustering

[24]Because we do not observe choices from a zero-interest budget and Figure 2 indicates substantial non-linearity in the demand curves, we used our structural model to estimate choices at R = 1 to further test the prediction about income levels when R = 1. We find strong support, for all combinations of delay length and whether the early payment occurs immediately. The minimum predicted zero-interest demand is €9.32 (S.E. = 0.25).

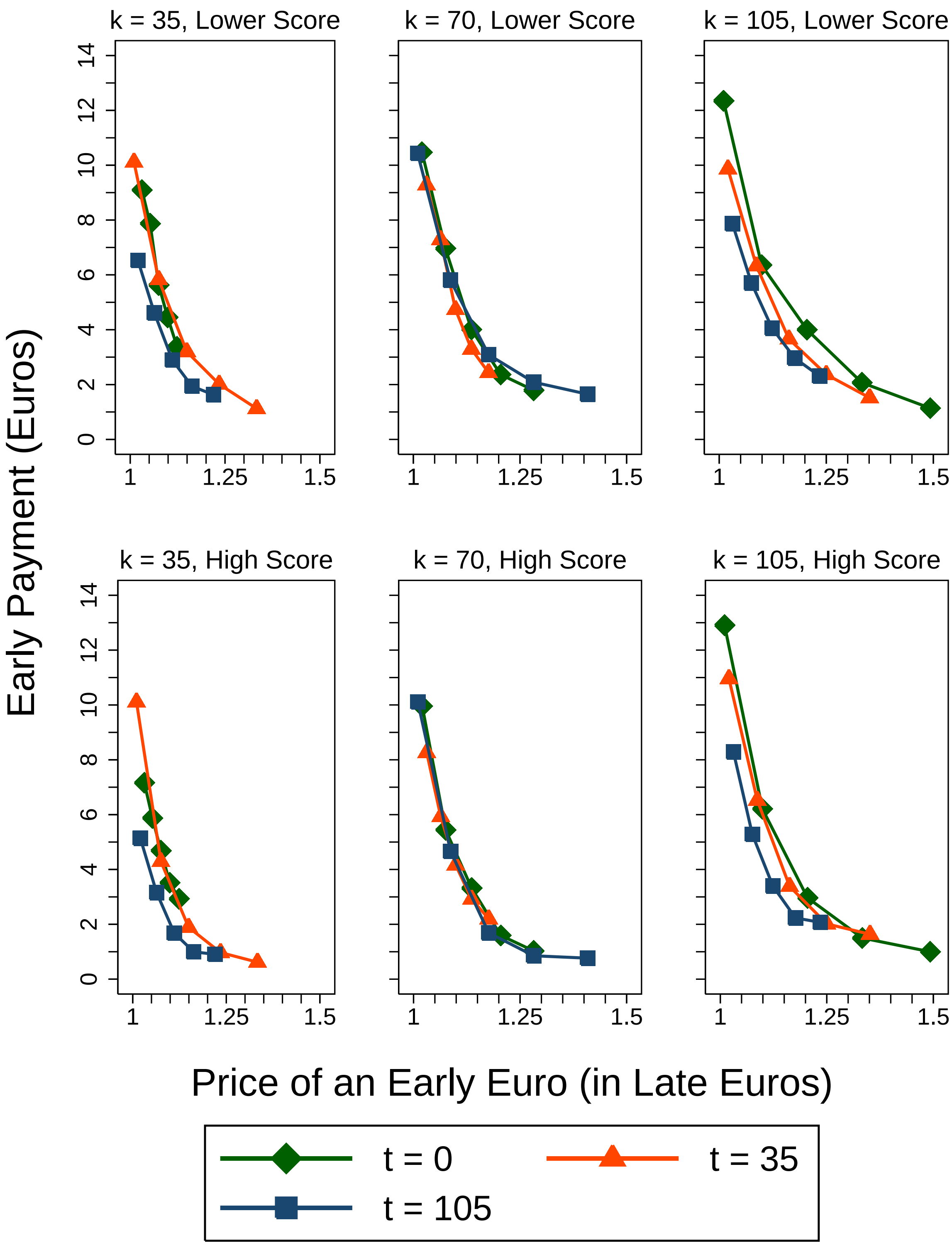

Figure 2: Demand Functions by Date of Early Payment, t, All Treatments

Table 2: Effect of Start Date, t, on Early Payment Demand

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
Constant ($t = 0$, $R = 1$)	8.256	8.679	7.840
	(0.437)	(0.608)	(0.627)
$1(t = 5$ weeks)	-0.521***	-0.678**	-0.367
	(0.192)	(0.264)	(0.278)
$1(t = 15$ weeks)	-1.324***	-1.308***	-1.340***
	(0.286)	(0.409)	(0.403)
Normalized Price Ratio ($R - 1$)	-21.365***	-21.535***	-21.197***
	(1.197)	(1.723)	(1.675)
Clusters	149	74	75
Observations	6705	3330	3375

$^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster.

standard errors at the individual level.[25] Table 2 presents the results of these regressions. If the date of first payment is immediate rather than 5 or 15 weeks in the future, lower-score subjects borrow significantly more of their endowment. High-score subjects do the same for only the 15 week delay.

Finally, we note that there are only small and statistically insignificant differences between the early payment choices of high- and lower-Baccalauréat-score participants in our overall sample, which combines all treatments. Specifically, lower-score participants select a slightly higher overall level of early payment, and display slightly more present bias (which may be taken as a proxy of impulsivity), but neither gap is significant at conventional levels.[26] As the next section shows, however, this aggregate result obscures sizeable differences in the effects of treatment on the behavior of high- versus lower-score participants.

[25] A regression approach is necessary because price ratios are not exactly balanced across the t dimension.

[26] Averaged across all choices, lower-score subjects allocate about €0.70 more experimental income (S.E. = 0.54, clustered by individual) to the earlier payment date than high-score participants. This difference is not significant. We add interaction terms between the dummy variables for t = 5 and t = 15 and high-score as well as a high-score level effect into the present bias regressions from Table 2. The gap between early demand when t = 0 versus t = 5 is about €0.31 smaller for high-score participants, but this difference is not significant (S.E. = 0.38). The signs and significances of the non-interacted dummies are unaffected.

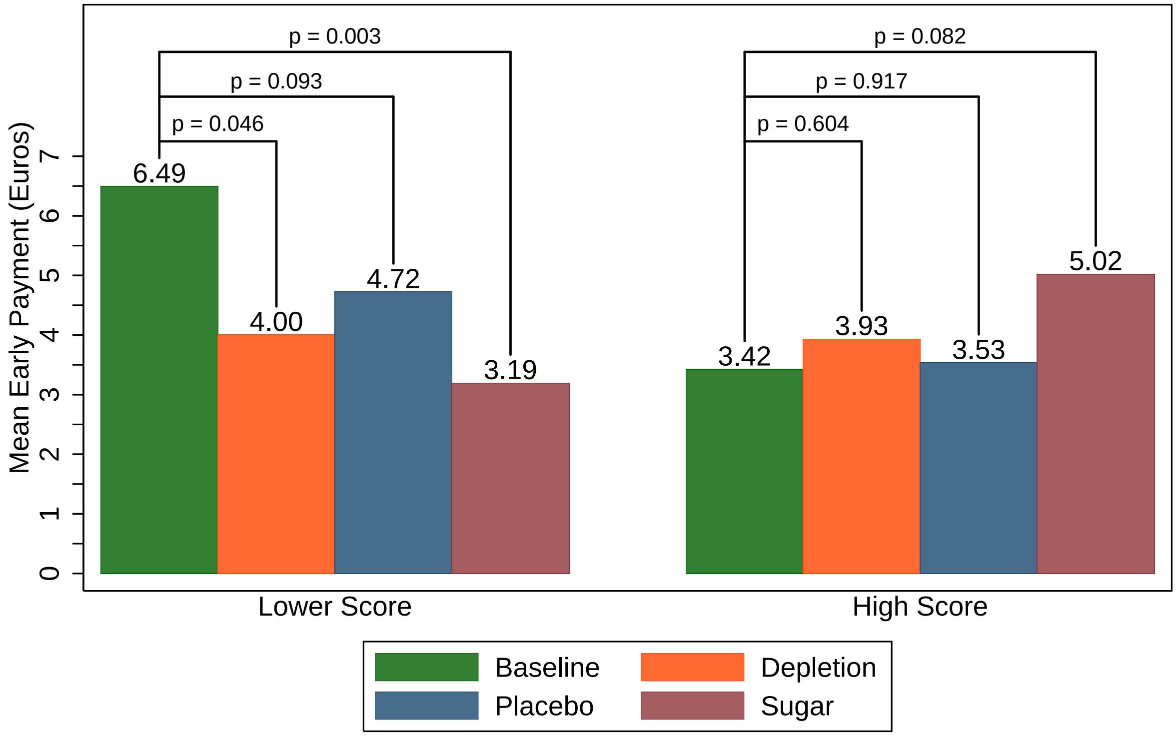

Figure 3: Mean Demand by Treatment

p-values are generated from regressions of the chosen early payment on treatment status with standard errors clustered at the individual level. The regression is run separately for lower- and high-score subjects. Each individuals makes 45 decisions, leaving us with a sample size of 3330 (74 clusters) in the lower-score group and 3365 (75 clusters) in the high-score group. An approach that collapses the data to individual-level means yields similar results.

3.2 Simple Estimates of Treatment Effects

Our first look at the effects of the various treatments is non-parametric. Figure 3 presents the mean demand for early payments across the Baseline, Depletion, Placebo and Sugar treatments by Baccalauréat score. Since these comparisons are between individuals, the treatments are balanced with respect to prices, delays and start dates.

Result 3 - For the lower test score sample, depletion, a sugared drink and a non-sugared drink all reduce the demand for early payment. All of these treatment effects are absent among participants with very high test scores.

Relative to the baseline condition, all three treatments significantly reduce demand for early income amongst lower-score participants. The strongest effect is for the sugar treatment (average demand for early payment reduced by 51% relative to baseline), with reductions of 38% and 27% for the depletion and placebo treatments respectively. The difference between the the sugar and placebo effects is significant (p = 0.056), suggesting some biologically-based effects of blood glucose.[27] The magnitude of this additional sugar effect (32% relative to the Placebo) is roughly the same size as the initial beverage effect, suggesting a modest role for body energy budgets relative to the other situational factors. Turning to the high-scoring subjects, only the sugar treatment affects the demand for early income significantly (and *positively*) of the high-score subjects (average demand increased by 47%). This effect is not precise, however. It does not significantly differ from the placebo effect at conventional levels (p = 0.143). Tobit regressions that specify censoring points at the corner solutions obtain results that are qualitatively identical.

Another noteworthy aspect of Figure 3 is that high- and lower-score subjects differ substantially in their Baseline choices; the difference of €3.07 between the groups' early payment demand in the Baseline is highly significant (p = 0.011). Recalling that there was no overall difference between high- and lower-score participants, this suggests that our three interventions have the effect of narrowing the difference in choices between high- and lower-score participants by reducing lower-scoring participants' demand for early payments. The next result probes the sources of these effects further.

Result 4 - The negative effect of all three treatments on lower-score participants' demand for early payments is strongest in cases where the price of early income is high.

Figures A2 and A3 in Appendix plot the demand curves for early payments for each (t, k) pair for lower-score and high-score participants, respectively. The lower-score subjects exhibit a similar level of demand across all treatments at low price levels. As the price of early income rises, early payments decline more rapidly in the Depletion, Sugar, and Placebo treatments than in the Baseline. The high-score participants show a similar level of demand to the lower-score participants at low prices, but demand is highly price-sensitive in all four treatments. Thus, the

[27] We use participants' estimates of the calories their beverage contained in order to ascertain whether this difference is due to psychology or physiology. Amongst lower-score subjects, there is no evidence that the magnitude of the Sugar-Placebo gap is affected by the beliefs about the drink or that beliefs themselves generate differences in demand.

Table 3: **Treatment Effect on Early Payment Demand by Price Level**

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
Constant (Low price, Baseline)	7.976	8.809	6.449
	(0.803)	(1.036)	(1.146)
Low price X Depletion	-1.778	-2.585	-0.276
	(1.093)	(1.590)	(1.460)
Low price X Placebo	-0.865	-0.944	-0.492
	(1.074)	(1.316)	(1.703)
Low price X Sugar	-0.530	-2.569	1.444
	(1.073)	(1.567)	(1.433)
Medium price	-4.423***	-3.848***	-5.477***
	(0.534)	(0.645)	(0.876)
Medium price X Depletion	-1.287	-2.559**	1.171
	(1.862)	(1.171)	(0.844)
Medium price X Placebo	-1.416*	-2.578**	0.789
	(0.793)	(1.040)	(0.754)
Medium price X Sugar	-1.194	-4.321***	2.024**
	(0.803)	(0.943)	(0.657)
High price	-5.764***	-5.550***	-6.157***
	(0.739)	(0.831)	(1.038)
High price X Depletion	-0.806	-2.019**	1.264*
	(0.738)	(1.010)	(0.653)
High price X Placebo	-1.393**	-2.271**	0.268
	(0.686)	(0.967)	(0.454)
High price X Sugar	-1.208*	-3.020***	0.995**
	(0.686)	(0.883)	(0.441)
Clusters	149	74	75
Observations	6705	3330	3375

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster.

treatments make the lower-score participants more price-sensitive, and thus more similar to the high-score participants' behavior.

To determine the statistical significance of the above effects, we define three price levels based on the relative value of early tokens. When early tokens are worth €0.90 or more we say the price is low, when they are worth between €0.80 and €0.90, we say the price is medium and when they are worth €0.80 or less, we say the price is high.[28] Table 3 presents OLS regressions of early payment demand on the treatment dummy variables split by price level. At medium and high prices all three treatments have significant effects for the lower-score group and the magnitude of the sugar effect is larger at high as opposed to low prices. The sugar effect is significantly greater than the placebo effect in the medium price condition (p = 0.003) and borderline significantly greater in the high price condition (p = 0.105). At both medium and high prices, the effect of the placebo beverage (relative to the baseline) is larger in magnitude than the difference between the sugared- and sugar-free drink.[29] Column (3) suggests an elasticity-reducing effect of the Sugar treatment on the high-score subjects, but the effects are not statistically different from the Placebo effects in either medium or high price condition (p = 0.132 and p = 0.218 respectively).

In sum, our nonparametric analysis shows that all three treatments (Depletion, Placebo and Sugar) reduce early demand among subjects with lower Baccalauréat test scores, who are more representative of the educated French population than our high-score sample. This apparent increase in 'patience' occurs only when the price of early income is high, so the treatments effectively make lower-score subjects more price-sensitive and therefore their overall behavior more similar to our 'elite' sample.

3.3 Treatment Effects in a Structural Model of Time Preferences

To measure whether the treatments affected different aspects of participants' preferences,[30] we now estimate a simple structural model of intertemporal preferences in which the treatments can affect each one of the fundamental utility parameters (specifically, their discount rate, present bias and

[28] Note that this definition focuses on the most salient aspect of the price presented to the participants: the changing value of an early token within a particular choice screen (t, k combination). Thus, the ranking is different than one based on annualized interest rate.

[29] In the medium-price case, the sugar-free drink reduces early consumption by €2.578, while the additional effect of adding sugar to the drink is a reduction of (€4.321 - €2.578 =) €1.743. In the high price case, these two effects are €2.271 and €0.749 respectively. The p-values associated with these comparisions are 0.546 and 0.219 respectively.

[30] For example, while reduced utility curvature (higher α) is associated with higher price-sensitivity, it should also increase the response to k (the gap between the payment dates). In general, because the demand functions implied by most theoretically interesting demand functions are nonlinear, the predicted marginal effects of each parameter depend on the levels of all the others, making simple regression tests only roughly informative about the effects of treatments on preference parameters.

intertemporal substitution parameters). One primary advantage of the CTB method is that it allows for the precise estimation of the parameters of structural models of intertemporal choice, even on the individual level. We will consider two types of structural treatment effects: aggregate and individual. Aggregate effects compare one treatment-specific parameter estimate to another and individual effects compare the set of individual-specific parameter estimates within one treatment to those from another. The two approaches yield similar results. As in section 3.2, splitting the sample by test score is essential for understanding the treatment effects.

We first provide a characterization of an individual's decision problem. Consider individual i making decision j. Continue to denote X as the number of tokens received at the earlier date and Y the number at the later date. Individual i is assumed to have power income utility (with exponent α) that is additively separable across time periods in a β-δ form (Laibson 1997; O'Donoghue and Rabin 1999). Choice j is characterized by the price of sooner income, R, a delay between the two payment dates, k, and an indicator for whether or not the sooner date is today, T (equal to 1 if t = 0, and 0 otherwise). As in equation (1), M is the total number of tokens available. We suppose that subjects optimize in the following way:[31]

$$(X_{ij}, Y_{ij}) = \underset{X,Y}{\arg\max} \quad X^{\alpha} + \beta^{T_j}\delta^{k_j}Y^{\alpha} \quad \text{subject to} \quad R_j X + Y \leq M. \tag{2}$$

To identify preferences, we follow the approach of AS by applying non-linear least squares (NLS) to the demand function for sooner tokens, derived directly from equation 2. This approach yields the structural regression equation

$$X_{ij} = \frac{M(\beta_j^T \delta_j^k R_j)^{\frac{1}{\alpha-1}}}{1 + R_j(\beta_j^T \delta_j^k R_j)^{\frac{1}{\alpha 0-1}}} + \epsilon_{ij}. \tag{3}$$

To analyze and test treatment effects, we replace α with

$$\alpha_1 + \alpha_2 D_i + \alpha_3 P_i + \alpha_4 S_i, \tag{4}$$

[31]Note that equation (1) implies that the set of available allocations is convex: that the tokens can be infinitely divided. While we offer subjects 17 possible allocations along the budget frontier rather than an infinite number, we argue that this is a suitable approximation to convexity. Andreoni, Kuhn and Sprenger (2013) perform a similar exercise with 6 allocations and find no evidence of bias due to discretization.

where D, P and S are treatment indicator variables, and make similar substitutions for β and δ. Instead of presenting results on δ itself, we use $r = \delta^{-365} - 1$, the yearly discount rate equivalent, for ease of interpretation.

Setting out the structural form in (2)-(4) allows us to be more precise about how our manipulations of the cognitive and physiological environments affect subjects' intertemporal choices than the more generic notions of 'impatience' or 'impulsivity'. For example, if a treatment raises r, it should increase subjects' demand for early rewards relative to late rewards regardless of the amount of delay between the two payment dates, and regardless of whether the early period corresponds to the date of the experiment or a future date. If a treatment lowers β (the present bias parameter) below 1, it increases subjects' attraction only to rewards that are received on the date of the experiment; high levels of present bias (low values of β) generate temporal inconsistencies in choices that may correspond to psychological notions of a failure of willpower (*i.e.* a greater impulsiveness). Finally, if treatments increase α, they make subjects more responsive to the costs of early income, which under some conditions (i.e. access to capital markets) might also be interpreted as an 'improvement' in the effectiveness of subjects' decisions. All three notions are conflated in the more amorphous notion of willpower that is often used to interpret experimental results on the effects of willpower depletion.

We first estimated equation (3) without treatment effects, following our modification of the CTB technique introduced by AS in the calibration of prices. Our estimate of the aggregate yearly discount rate is 21.8% for lower-score types (S.E. = 5.9%) and 21.0% for high-score types (S.E. = 4.1%).[32] Our estimate of the β parameter is 0.976 (S.E. = 0.008) for lower-score and 0.988 (S.E. = 0.007) for high-score, with both values significantly less than 1 (p = 0.005 and p = 0.086, respectively). Thus, in contrast to AS who estimate β = 1.007 (S.E. = 0.006), we find evidence of present bias in the β-δ form.[33] Lastly, we estimate a lower degree of curvature –α = 0.922 (S.E. = 0.008) for lower-score and 0.942 (S.E. = 0.005) for high-score individuals– as opposed to 0.897 (S.E. = 0.009) in AS.

[32]The corresponding specification from AS (Table 2, column (3)) estimates a rate of 37.7% with a standard error of 8.7%. Because our max time horizon is slightly longer, we would expect a slightly lower estimate of the rate if individuals display some insensitivity to the exactness of dates far in the future.

[33]While this magnitude of present bias over pure allocations of money is not economically meaningful in our experiment, a 3% distortion of preferences could be very important for major financial decisions.

Result 5 - The treatment effects on the structural parameters are concentrated on α, the utility function curvature parameter. The magnitudes are economically significant at interest rates that correspond to predatory credit instruments.

Table 4 presents estimates of treatment effects on the parameters of a common utility function, shared by all individuals in each estimation sample. The treatment effects only show up as significant for utility curvature. Both Drink treatments significantly decrease lower-score curvature (Baseline α = 0.860, Placebo α = 0.946, Sugar α = 0.965), and the estimates are precise enough to conclude the effect is significantly larger for the sugared drink (p = 0.043). The marginal effect of sugar of α (0.105 - 0.087 = 0.018) is much smaller than the effect of the placebo beverage (0.087). The Depletion treatment has a weaker effect (Depletion α = 0.917). Additionally, the joint hypothesis that the α and β effects are zero is rejected (p = 0.088). The two Drink treatments have significant joint effects as well; the joint effects on all three parameters are jointly different from zero in the Placebo treatment (p = 0.021) and in the Sugar treatment (p = 0.001) for the lower-score sample. While the high-score curvature increase is significant only for the Sugar treatment (Baseline α = 0.961, Sugar α = 0.931), this effect is not significantly different from the effect of the Placebo treatment (p = 0.167).

The fact that the treatment effects operate through utility curvature is consistent with Result 4: they make the lower-score individuals more price sensitive. In the limiting case where the utility function has no curvature, optimal choices move from one corner to the other as prices change. The less curvature the function has, the closer we are to this case, and the more responsive individuals will be. The more curvature the function has, the more we should observe choices that don't respond fully to extreme prices. To illustrate this, consider subjects from our experiment making a decision about taking a 2-week payday loan against a €1000 paycheck that comes with a 15% charge (APR = 390%). Roughly, the optimal loan for a lower-score, Baseline treatment individual is €310, which results in a €60 charge. Holding the discount and present-bias factors constant and switching to the Depletion curvature estimate reduces the loan to €220 (charge of €40), the Placebo curvature estimate to €140 (charge of €20) and the Sugar curvature estimate to €60 (charge of €10).

Table 4: Treatment Effects on Aggregate Utility Parameter Estimates

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
α **(Utility Curvature)**			
Constant (Baseline)	0.904	0.860	0.961
	(0.015)	(0.027)	(0.007)
Depletion Effect	0.028	0.058*	-0.016
	(0.018)	(0.031)	(0.013)
Placebo Effect	0.042**	0.087***	-0.014
	(0.016)	(0.028)	(0.013)
Sugar Effect	0.036**	0.105***	-0.030***
	(0.016)	(0.028)	(0.011)
β **(Present Bias)**			
Constant (Baseline)	0.979	0.949	1.002
	(0.016)	(0.026)	(0.013)
Depletion Effect	0.006	0.045	-0.023
	(0.018)	(0.027)	(0.018)
Placebo Effect	0.004	0.031	-0.014
	(0.018)	(0.029)	(0.018)
Sugar Effect	0.004	0.025	-0.016
	(0.019)	(0.029)	(0.018)
r **(Annual Discount Rate)**			
Constant (Baseline)	0.268	0.357	0.210
	(0.106)	(0.225)	(0.068)
Depletion Effect	-0.140	-0.267	-0.057
	(0.124)	(0.256)	(0.097)
Placebo Effect	-0.046	-0.076	-0.076
	(0.121)	(0.236)	(0.114)
Sugar Effect	-0.016	-0.219	0.109
	(0.122)	(0.237)	(0.107)
Clusters	149	74	75
Observations	6705	3330	3375

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster.

Table 5: **Treatment Effects on Median Individual Utility Parameter Estimates**

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
α **(Utility Curvature)**			
Constant (Baseline)	0.958	0.940	0.974
	(0.009)	(0.011)	(0.008)
Depletion Effect	0.016	0.023*	0.008
	(0.010)	(0.013)	(0.014)
Placebo Effect	0.012	0.027*	0.005
	(0.012)	(0.015)	(0.019)
Sugar Effect	0.010	0.039***	-0.011
	(0.011)	(0.013)	(0.011)
β **(Present Bias)**			
Constant (Baseline)	0.979	0.949	1.013
	(0.026)	(0.028)	(0.014)
Depletion Effect	-0.002	0.041	-0.035**
	(0.027)	(0.030)	(0.016)
Placebo Effect	0.013	0.047	-0.023
	(0.026)	(0.030)	(0.019)
Sugar Effect	-0.001	0.018	-0.035*
	(0.029)	(0.037)	(0.019)
r **(Annual Discount Rate)**			
Constant (Baseline)	0.323	0.490	0.323
	(0.104)	(0.250)	(0.073)
Depletion Effect	0.048	0.017	-0.081
	(0.143)	(0.285)	(0.140)
Placebo Effect	0.105	-0.040	-0.034
	(0.148)	(0.272)	(0.192)
Sugar Effect	-0.000	-0.311	0.109
	(0.130)	(0.273)	(0.149)
Observations	104	46	58

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Standard Errors in parentheses. Parameter estimate distributions trimmed at the 5th and 95th percentiles.

Turning now to our method that allows each subject to have his/her own set of utility parameters, (α, β and r), we make a couple of adaptations that are dictated by the estimation results. First, we drop 21 individuals who lack enough choice variation for the successful estimation of the parameters. Second, because using the NLS technique with only 45 observations per subject delivers some extreme outlying estimates, we trim the sample at the 5th and 95th percentiles of the distribution of all three parameter estimates. This excludes 24 more subjects, leaving a sample of 104. Of the 45 excluded subjects, 28 are from the lower-score sample and 17 are from the high-score sample.

Table 5 reports estimates of treatment effects on the individual-specific parameters using quantile regressions at the median value of the estimate distribution. Specifically, for each of the three parameters, we estimated a median regression on 104 observations in which the participant's parameter estimate was the dependent variable and the three treatment indicators were the only regressors. Standard errors for these estimates are obtained via bootstrap. The estimated individual effects are largely consistent with the aggregate effects. Both drinks significantly decrease curvature in the lower-score sample, whereas the depletion effect on curvature is weaker but still marginally significant. One puzzle is that the treatments appear to have present-bias inducing effects for the high-score group in this specification.

All three treatments increase the amount of deferred income for the lower-score individuals by reducing utility curvature such that budgets featuring above-market interest rates generate large differences in allocations versus the Baseline. There exists some evidence that the Sugar treatment had stronger effects than the Placebo treatment.

3.4 Robustness

While our structural estimation procedure uses both interior and 'corner' choices to identify the utility parameters, and while the procedure is compatible with any finite level of intertemporal substitutability, a possible concern is that the method breaks down in the limiting case of infinite substitutability across time periods, where all choices are predicted to be at corners.[34] Since our

[34]This is a consequence of assuming that individuals evaluate the utility of lab earnings as prospects independent of background consumption. One approach to this issue would be to incorporate background payments into the structural estimation. Since background consumption is independent of treatments this would have little effect on the results.

Table 6: Corner Choice by Treatment

Treatment	*All Subjects*	*Lower-Score*	*High-Score*
	(1)	(2)	(3)
Baseline	24% Sooner Corner 47% Later Corner 29% Interior	29% Sooner Corner 34% Later Corner 37% Interior	16% Sooner Corner 71% Later Corner 13% Interior
Depletion	18% Sooner Corner 62% Later Corner 20% Interior	15% Sooner Corner 56% Later Corner 29% Interior	21% Sooner Corner 68% Later Corner 11% Interior
Placebo	19% Sooner Corner 58% Later Corner 23% Interior	21% Sooner Corner 52% Later Corner 27% Interior	15% Sooner Corner 67% Later Corner 18% Interior
Sugar	18% Sooner Corner 53% Later Corner 29% Interior	13% Sooner Corner 65% Later Corner 22% Interior	20% Sooner Corner 49% Later Corner 31% Interior

structural estimates suggest a high degree of substitutability, and since a substantial share of our subjects' choices are, in fact, at corners, we also studied treatment effects on the frequency and type of corner solutions in two less parametric ways. The first of these, in Table 6, shows the frequency of interior solutions and the two types of corner solution, by treatment.

While the overall share of corner solutions in Table 6 is high at 75% (consistent with AS and with Andreoni *et al.* 2013), column (2) also clearly shows that all treatments reduce interior choice frequency among our lower Baccalauréat score participants. The especially pronounced increase in later corner choices for this group is related to the economically, but not statistically significant changes to the discount rate induced by the treatments.

Our second approach was to estimate treatment effects in a multinomial logit specification with three choice options: 1) sooner corner, 2) interior and 3) later corner. Results are found in Appendix Table A4. Reassuringly, in the lower-score sample, the probability of choosing the sooner corner is significantly lower in the Depletion and Sugar treatments than the Baseline, and the probability of choosing the later corner is significantly greater in the Depletion, Sugar and Placebo treatments.

If time preferences are indeed dependent on physiological conditions, it would be encouraging if our treatment effects were moderated by the condition in which individual subjects entered the lab. While subjects were asked not to eat or drink for at least three hours prior to the experiment, our survey indicated that there was substantial variation in the degree of adherence to this request.

Almost 19% of individuals report they had not eaten since the day before the experiment and around 7% had eaten within the three hour window prior to the experiment. We expect that subjects should have been more susceptible to the interventions the longer they went without eating. Table 7 presents treatment effect regressions on demand for early payment with interactions between the Depletion, Placebo and Sugar variables with the number of hours since last meal.

Consistent with our baseline results, we find no significant meal-time correlations for the high-scoring subjects; this group's decisions are also unaffected by the amount of elapsed time since their last meal. Lower-scoring subjects, on the other hand, become less patient as the time since their last meal increases; this behavior is consistent with Briers *et al.*'s (2006) and Danziger *et al.*'s (2011) evidence.[35] Also, as predicted, lower-scoring subjects' sensitivity to all three of our interventions increases with elapsed time since their last meal.[36] While this may not be surprising for the drink treatments, it is perhaps noteworthy that the Stroop test also has a larger patience-enhancing effect on hungry than on recently-nourished subjects. This finding reinforces our suggestion that engaging in a cognitively demanding task that requires resisting one's immediate impulse can (at least temporarily) improve a vulnerable subject's ability to focus on subsequent economic decisions.

To rule out mood or affect as potential drivers of our sugar or placebo effects, we use the elicited mood and beverage enjoyment data from the post-drink surveys (Drink treatments) and entry surveys (Baseline).[37] First and foremost, mood is not predictive of demand in our experiment. Second, we use a specification identical to our hours-since-last-meal analysis, but replace that variable with the self-reported mood variable, and exclude individuals from the Depletion treatment (since their mood elicitation took place prior to the Stroop task). Results are in Appendix Tables A2 and A3. We again find no substantive evidence that mood is related to demand for lower-score participants.[38]

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[35] Briers *et al.* found that the desire for caloric resources increases the desire for money. Looking at decisions made by an Israeli parole board, Danziger *et al.* found that parole was much more likely to be granted early in the day than later in the day, conditional on crime, sentence and ethnicity. Since a judge's reputation is harmed more by inappropriately granting, as opposed to inappropriately refusing parole, fatigued judges 'take the easy way out' relative to rested judges. Following the board's midmorning snack, there was a substantial spike in the percentage of prisoners who were granted parole.

[36] Note that the uninteracted treatment effects no longer enter as significant because they are estimates specific to the intercept where the time since last meal is zero.

[37] Both mood and beverage enjoyment are elicited as numbers from 1 (negative) to 10 (positive).

[38] The same is true of elicited beverage enjoyment. Attempts to replicate the Ifcher and Zarghamee (2011) result by

Table 7: Treatment Effect on Early Payment Demand with Meal Time Controls

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
Constant (Baseline, just ate)	2.838	2.360	3.735
	(1.248)	(1.287)	(1.509)
Depletion Effect	1.357	1.281	1.401
	(1.645)	(2.069)	(2.079)
Placebo Effect	0.080	1.419	-2.326
	(1.524)	(1.630)	(2.159)
Sugar Effect	2.591*	1.102	2.090
	(1.526)	(1.700)	(1.844)
Time since last meal (hours)	0.434**	0.730***	-0.049
	(0.218)	(0.155)	(0.223)
Time X Depletion	-0.474*	-0.677***	-0.217
	(0.261)	(0.241)	(0.301)
Time X Placebo	-0.183	-0.544**	0.421
	(0.246)	(0.214)	(0.289)
Time X Sugar	-0.608**	-0.773***	-0.122
	(0.250)	(0.232)	(0.270)
Clusters	149	74	75
Observations	6705	3330	3375

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster.

To add credence to our use of the Baccalauréat exam score as a measure of cognitive ability, we present treatment effect estimates split by CRT performance instead of by Baccalauréat score.[39] As noted, these estimates should be interpreted with caution since the treatments may have affected the subjects' CRT performance, just as they affected the subjects' performance in the time-preference task. That said, consistent with our results using the Baccalauréat, we find significant effects of the treatments on time preferences only for those who failed to answer a single CRT question correctly (slightly more than 70% of these individuals are in the lower-score group). Results are presented

using our treatment variables as instruments for mood fail due to a lack of relevance: our treatments do not appear to affect mood.

[39]As mentioned earlier, CRT and Baccalauréat performance are positively and significantly correlated.

Table 8: Treatment Effect on Early Payment Demand by CRT Score

	Estimation Sample			
	CRT = 0	***CRT = 1***	***CRT = 2***	***CRT = 3***
	(1)	(2)	(3)	(4)
Constant (Baseline)	6.916	5.061	3.039	4.654
	(0.997)	(0.965)	(1.165)	(2.410)
Depletion Effect	-3.580**	-1.457	0.796	1.296
	(1.405)	(1.635)	(1.345)	(3.015)
Placebo Effect	-2.468*	0.251	0.096	-0.726
	(1.240)	(1.319)	(1.653)	(2.559)
Sugar Effect	-2.409*	-0.217	1.143.	-0.299
	(1.351)	(1.260)	(1.728)	(2.599)
Clusters	42	40	40	27
Observations	1890	1800	1800	1215

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster.

in Table 8.[40]

4 Discussion

This paper studies the effects of prior impulse-controlling activity and sugar consumption on time preferences. A key innovation of our approach is an explicit model of intertemporal choice, which allows us to distinguish three aspects of 'patience' that might be affected by the cognitive and physiological environment: discount rates, present bias, and price sensitivity. We find that intertemporal choices are sensitive to transient features of the choice environment, but not necessarily in ways that are consistent with a willpower-based model. For example, exposure to the Stroop (1935) task prior to the elicitation of time preferences makes lower-test-score participants *more* responsive to high prices for early income. It is as if the Stroop test primed the subjects to think more carefully about their subsequent economic decisions. One interpretation is that Stroop-exposed subjects

[40]Table 8's presentation of results for each possible CRT score raises the question of how our main results would change using a finer breakdown of Baccalaurat scores than whether subjects are above or below the median. To that end, appendix Figure A4 shows demand for early payments as cubic functions of Baccalauréat score. The results are mostly similar, although they do show a strong sugar effect at the very bottom of the cognitive ability distribution.

paid greater attention to the arbitrage opportunities available to them in capital markets, resulting in more price-sensitive choices.[41] While this result contrasts with previous experiments showing that prior impulse control reduces subjects' performance on subsequent impulse-control tasks, we note that the time-preference task in our experiment differs in important ways from the outcomes studied in those experiments. In particular, because we offer subjects a menu of choices where they choose how much to save or borrow –rather than just saying 'yes' or 'no' to a given amount of income today–, our time-preference task may be less conducive to 'snap' or thoughtless decision-making. While it is unclear which type of task is more representative of the types of consumer financial decisions –such as payday loans– we are trying to model, our surprising results still cast doubt on energy-budget-based models for a large class of financial decisions consumers make.

We also find that drinking either a sugar-free or a sugared beverage ten minutes prior to the time preference task increases patience, and does so by raising subjects' sensitivity to high prices. The magnitude of the sugar effect is significantly greater than the magnitude of the placebo effect, consistent with a role for blood glucose. However, the finding that the placebo beverage has an effect relative to the baseline, which in many specifications is larger than the marginal effect of sugar, raises questions about the importance of blood glucose relative to other situational factors.[42] It is also possible that the distinct nature of our time-preference task accounts for the relatively small effect of sugar consumption, relative to other situational factors. In sum, our results raise questions about the importance of willpower-based models as the most appropriate way to conceptualize a large class of consumer decisions.

This said, we emphasize that our results do not imply that consumers' financial decisions are immune from situational factors; indeed our estimated treatment effects are large in magnitude. For example, the estimated changes in utility-function curvature (α) associated with our Deple-

[41] Carvalho *et al.* (2013) study the effects of randomly providing individuals with a savings account on time preferences. Echoing our results, their treatment effects are concentrated on utility curvature: subjects with new accounts exhibit more linear preferences, suggesting increased sensitivity of choices to market options.

[42] Indeed, recent findings by Molden *et al.* (2012) and Sanders *et al.* (2012) show that simply rinsing one's mouth with a sugared beverage without swallowing (with no effect on blood glucose) bolsters impulse control in similar ways to ingesting sugar; related neurological evidence indicates that the sensing of the carbohydrate in the mouth activates a part of the brain that is highly sensitive to incentives (Kringelbach 2004; Chambers *et al.* 2009). Since our placebo drink did contain a very small amount of sugar –though not enough to affect blood glucose levels– this mechanism could account for our findings. An alternative explanation is that the drinks could be perceived as a reward, which might have the effect of reducing subjects' desire for an immediate secondary reward. One difficulty with this hypothesis, however, is that the drinks should act primarily on subjects' present bias, not on their price-sensitivity; the drinks should also affect both lower- and higher-score subjects, which is not what we observe.

tion, Placebo and Sugar treatments reduce the predicted demand for a typical payday loan (two weeks at an APR of 390%, against a €1000 paycheck) from a baseline of €310 to €220, €140 and €60 respectively. The associated loan interest charges fall from €60 to €40, €20 and €10. Payday loans such as the above are considered by many to be 'predatory' in that their short-term nature takes advantage of scope insensitivity in interest rates to charge above-market rates. In these situations, our finding that all of the treatment effects operate through the intertemporal elasticity of substitution indicates that unless consumers are highly attuned to their task at hand, they may ignore substantial price differences across assets or credit payments.[43] While, as noted, all the above treatment effects are largely absent among subjects with very high cognitive abilities (corresponding to the top decile of French high school graduates), it is noteworthy that our 'lower-score' results pertain to a subject pool whose cognitive ability is still well above the national mean (representing about the 50th-90th percentiles of high school graduates), suggesting the possibility of even larger effects for the population as a whole.

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A Appendix for Online Publication

Figure A1: Glasses Containing either the Placebo or the Sugared Beverage

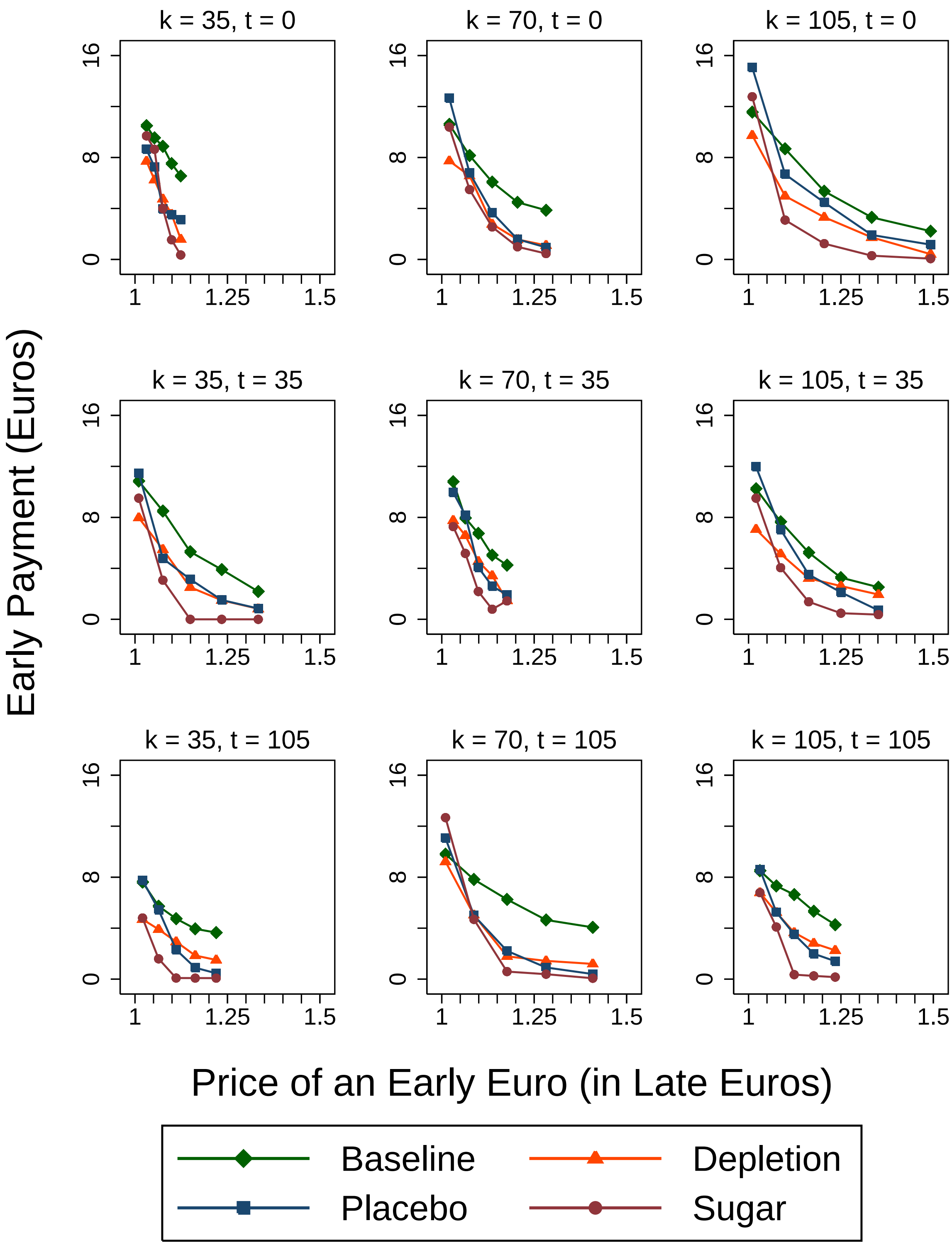


Figure A2: Demand Functions by Treatment, Lower-Score Sample

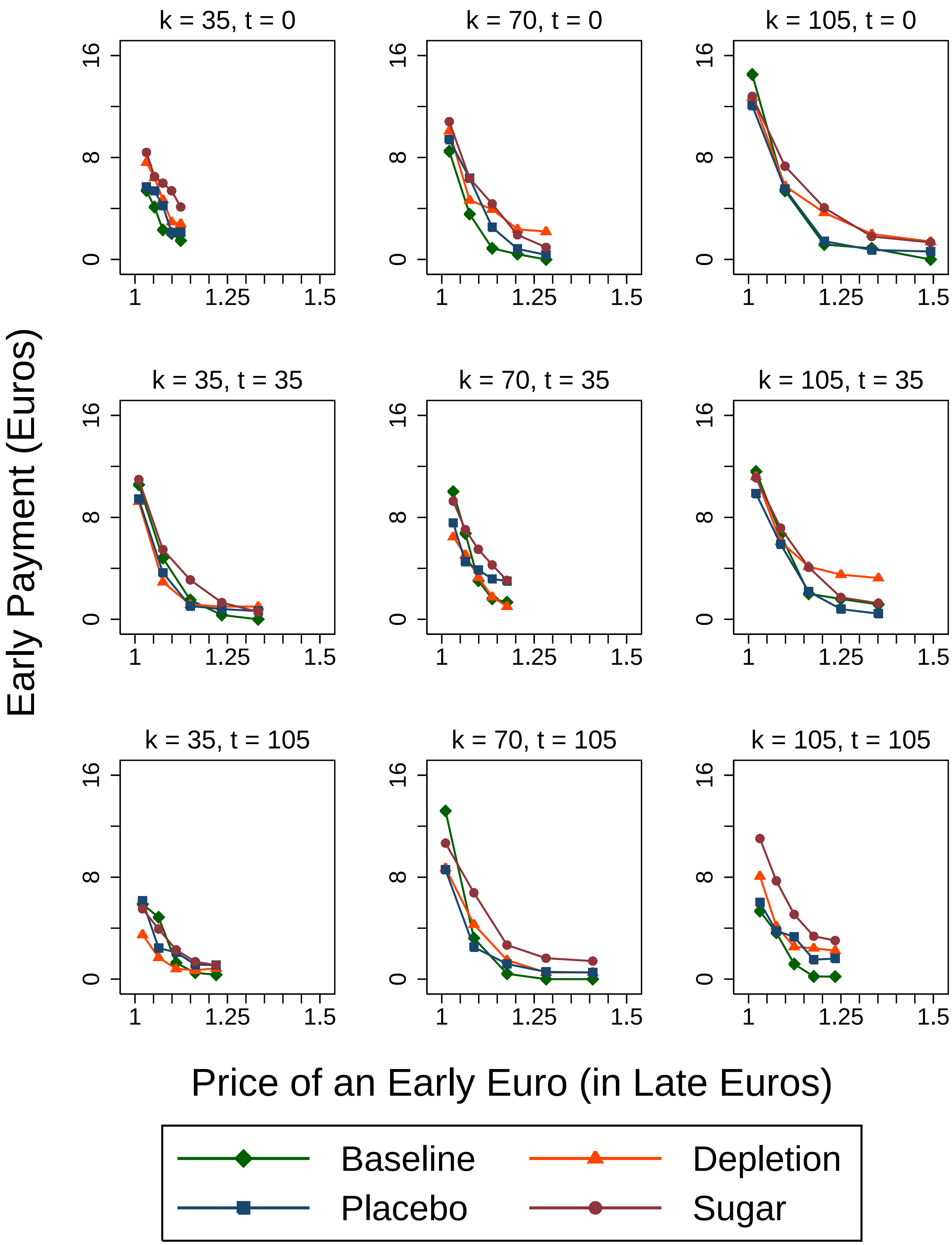


Figure A3: Demand Functions by Treatment, High-Score Sample

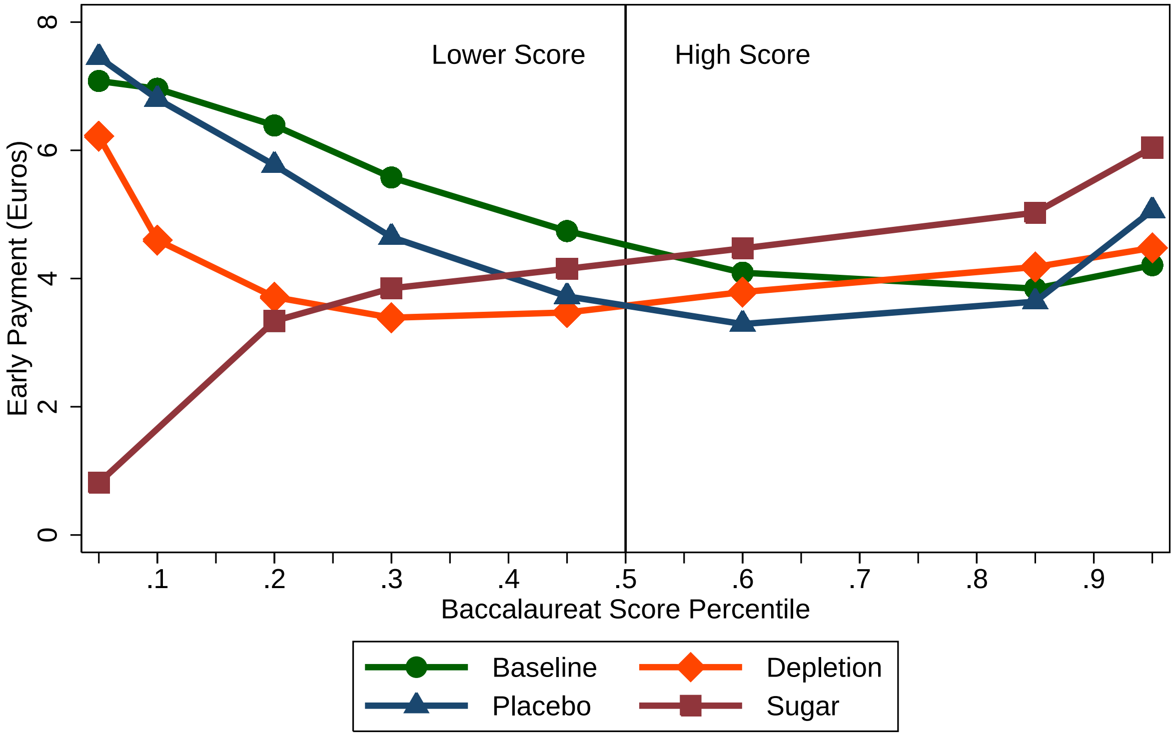


Figure A4: Predicted Demand using Baccalauréat Score Cubic

Predictions are from a regression of demand on a cubic in the subject's Baccalauréat Score. The data are trimmed in order to avoid estimating the polynomials on outliers.

Table A1: The 45 Choice Sets in the Time Preference Elicitation Task

			Parameter			
Choice number	Early date t	Delay length k	Early value of 1 token a_t	Price of an early Euro	Annual intrest rate %	Maximum early payoff
1	0	5	0.97	1.03	36	15.52
2	0	5	0.95	1.05	65	15.20
3	0	5	0.93	1.08	100	14.88
4	0	5	0.91	1.10	141	14.56
5	0	5	0.89	1.12	189	14.24
6	5	10	0.97	1.03	17	15.52
7	5	10	0.94	1.06	36	15.04
8	5	10	0.91	1.10	59	14.56
9	5	10	0.88	1.14	85	14.08
10	5	10	0.85	1.18	116	13.60
11	15	15	0.97	1.03	11	15.52
12	15	15	0.93	1.08	28	14.88
13	15	15	0.89	1.12	47	14.24
14	15	15	0.85	1.18	70	13.60
15	15	15	0.81	1.23	96	12.96
16	0	10	0.98	1.02	11	15.68
17	0	10	0.93	1.08	44	14.88
18	0	10	0.88	1.14	85	14.08
19	0	10	0.83	1.20	139	13.28
20	0	10	0.78	1.28	208	12.48
21	5	15	0.98	1.02	7	15.68
22	5	15	0.92	1.09	32	14.72
23	5	15	0.86	1.16	64	13.76
24	5	15	0.80	1.25	103	12.80
25	5	15	0.74	1.35	154	11.84
26	15	5	0.98	1.02	23	15.68
27	15	5	0.94	1.06	82	15.04
28	15	5	0.90	1.11	164	14.40
29	15	5	0.86	1.16	278	13.76
30	15	5	0.82	1.22	432	13.12
31	0	15	0.99	1.01	4	15.84
32	0	15	0.91	1.10	37	14.56
33	0	15	0.83	1.20	83	13.28
34	0	15	0.75	1.33	144	12.00
35	0	15	0.67	1.49	231	10.72
36	5	5	0.99	1.01	11	15.84
37	5	5	0.93	1.08	100	14.88
38	5	5	0.87	1.15	246	13.92
39	5	5	0.81	1.23	479	12.96
40	5	5	0.75	1.33	845	12.00
41	15	10	0.99	1.01	5	15.84
42	15	10	0.92	1.09	51	14.72
43	15	10	0.85	1.18	116	13.60
44	15	10	0.78	1.28	208	12.48
45	15	10	0.71	1.41	339	11.36

Table A2: Treatment Effect on Early Payment Demand with Mood Controls

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
Constant (Baseline, neutral mood)	5.168	7.898	2.638
	(2.506)	(3.551)	(2.112)
Placebo Effect	-1.144	-1.922	-0.412
	(0.834)	(1.163)	(0.998)
Sugar Effect	-0.878	-3.407***	1.567*
	(0.847)	(1.120)	(0.900)
Mood (-5 to 5 scale)	0.046	-0.260	0.160
	(0.438)	(0.598)	(0.424)
Mood X Placebo	-0.383	0.381	-1.008*
	(0.539)	(0.754)	(0.586)
Mood X Sugar	-0.141	0.648	-0.500
	(0.527)	(0.679)	(0.558)
Clusters	109	55	54
Observations	4905	2475	2430

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster. Mood is elicited on a 1-10 scale. We renormalize to -5 to 5 such that treatment effect estimates refer to neutral mood.

Table A3: Treatment Effect on Early Payment Demand with Drink Enjoyment Controls

	Estimation Sample		
	All Subjects	***Lower-Score***	***High-Score***
	(1)	(2)	(3)
Constant (Baseline, neutral enjoyment)	5.408	6.491	3.422
	(0.674)	(0.896)	(0.681)
Placebo Effect	-1.258	-1.852*	0.004
	(0.809)	(1.037)	(1.021)
Sugar Effect	-1.054	-3.344***	1.385
	(0.803)	(1.107)	(0.862)
Placebo X Enjoyment (-5 to 5 scale)	-0.231	-0.162	-0.318
	(0.160)	(0.172)	(0.277)
Sugar X Enjoyment (-5 to 5 scale)	0.296*	0.072	0.373*
	(0.172)	(0.191)	(0.196)
Clusters	109	55	54
Observations	4905	2475	2430

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster. Enjoyment is elicited on a 1-10 scale. We renormalize to -5 to 5 such that treatment effect estimates refer to neutral enjoyment.

Table A4: Treatment Effects on Probability of Corner Solution Choice

Marginal Effects from Multinomial Logit Model

	Estimation Sample					
	All Subjects		***Lower-Score***		***High-Score***	
Corner Choice:	Sooner	Later	Sooner	Later	Sooner	Later
	(1)	(2)	(3)	(4)	(5)	(6)
Constant (Basline)	0.242	0.472	0.287	0.344	0.161	0.706
	(0.046)	(0.060)	(0.066)	(0.072)	(0.038)	(0.069)
Depletion Effect	-0.063	0.149*	-0.142*	0.217**	0.049	-0.030
	(0.057)	(0.078)	(0.084)	(0.108)	(0.058)	(0.089)
Placebo Effect	-0.055	0.111	-0.077	0.179*	-0.009	-0.033
	(0.054)	(0.080)	(0.075)	(0.096)	(0.059)	(0.111)
Sugar Effect	-0.061	0.060	-1.156**	0.307***	0.040	-0.217**
	(0.054)	(0.078)	(0.071)	(0.105)	(0.053)	(0.091)
Clusters	149		74		75	
Observations	6705		3330		3375	

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Standard Errors in parentheses, clustered by individual. 45 observations (budgets) per cluster. The multinomial logit specification estimates the effect of our treatments on the probability of choosing either the sooner or later corner solution, with respect to an interior choice (all pooled). This table presents the marginal effects of changing the treatment indicators from 0 to 1, holding the other indicators constant at 0.

Instructions

You are about to participate in an experimental session on decision-making.

The session consists of several parts. You will receive the instructions for each part after the previous part has been completed.

Part 1

Your computer screen will display a number of questions. We thank you for answering these questions with care.

Once all participants will have answered these questions, we will distribute glasses of a beverage that we will invite you to drink. Please do not drink the beverage before being expressly invited to do it.

Next, you will have to answer a few questions.

After you have answered these questions, you will have to wait for the next part. During this rest period, you are allowed to read books, newspapers or magazines. During this part and throughout the session, it is not allowed to talk to the other participants.

Part 2

Your decisions

In this part, you will be asked to make a series of choices between payments you can receive at different dates. On each of nine decision screens, you will decide how to divide your payment for the experiment between two dates: an ‘early’ date and a ‘late’ date.

Altogether, you will make a total of 45 choices on the nine decision screens. These decision screens will be displayed in a random order. You will have the following options for payment dates:

Decide between payment <u>today</u> and payment in <u>5 weeks</u>

Decide between payment in <u>5 weeks</u> and payment in <u>15 weeks</u>

Decide between payment in <u>15 weeks</u> and payment in <u>30 weeks</u>

Decide between payment <u>today</u> and payment in 10<u> weeks</u>

Decide between payment in <u>5 weeks</u> and payment in <u>20 weeks</u>

Decide between payment in <u>15 weeks</u> and payment in <u>20 weeks</u>

Decide between payment <u>today</u> and payment in <u>15 weeks</u>

Decide between payment in <u>5 weeks</u> and payment in <u>10 weeks</u>

Decide between payment in <u>15 weeks</u> and payment <u>25 weeks</u>

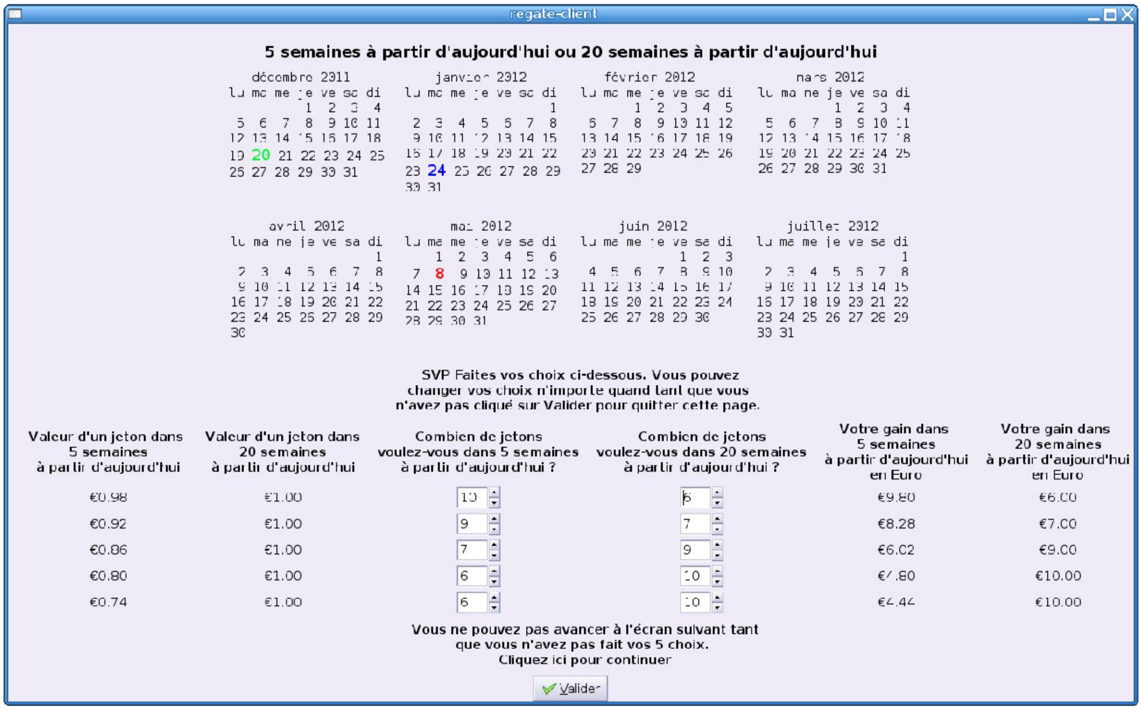
On each decision screen, we will provide you with the exact calendar dates of the above payments, so you know exactly which decision you are making. Today’s date appears in green, the early payment date appears in blue and the late payment date appears in red.

You will be given 16 tokens to divide in each choice, but *the value of a token changes from choice to choice*. The real money payments associated with your token choices will be automatically calculated for you to see as you make your decisions.

To make your decisions, you can enter a number for the early payment (or the late payment) and move the up and down arrows. The box corresponding to the late payment (or the early payment, respectively) will be automatically updated by a number indicating the difference between 16 and the tokens assigned to the other date of payment.

Once you have completed a set of five decisions, you must press the “Validate” button to move to the next decision screen.

Below is an example of a decision screen.



Your payment

At the end of the session, the computer program will randomly select one of the 45 decisions you made to be your earnings from participating in this experiment.

In addition, you will receive a €5 participation payment that will be split up into two payments of €2.50: one to go along with your earnings at the early and late dates associated with the randomly selected decision.

This means that you will not be paid in cash today. You will be paid by checks that will be mailed to you at the address you will indicate on the envelopes on your desk. We will mail the envelopes at the dates corresponding to the randomly selected decision.

For example, if the selected decision indicates that you have chosen *x* tokens today and *y* tokens in 10 weeks, we will mail the first check today and the second check in 10 weeks from today.

Remember that each decision could be the one that counts! Treat each decision as if it could be the one that determines your payment.

If you have any question on these instructions, please raise your hand and we will answer your questions in private.

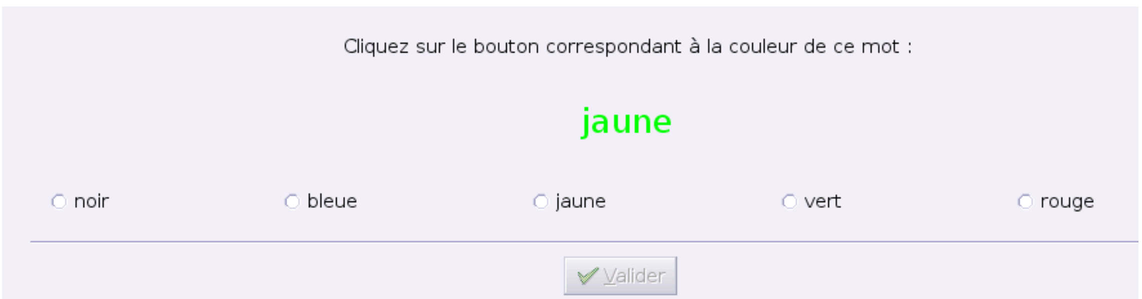
Part 3

In this part, you will be presented with a series of color words (black, blue, yellow, green, red). These words will appear in different colors, sometimes matching the word (e.g., the word blue, written in blue), and sometimes not matching the word (e.g., the word blue, written in red).

Your job is to indicate, as quickly and accurately as possible, the color in which the word is written, whether or not that matches the word itself. Click the button that matches the color of the word. Try not to pay attention to the word, but just the color.

This task will last for six minutes.

Example :



In this example, the correct answer is « green ».