Does experience with high inflation affect intertemporal decision making?

Sensitivity to inflation rates in Argentine and British delay discounting choices

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Abstract

Delay discounting captures the way in which people devalue rewards which are not immediately available as a function of their delay until receipt. Normatively, decision makers should be sensitive to inflation rates when evaluating delayed rewards because the value of a delayed outcome is eroded by inflation. We hypothesised that participants from countries with direct experience of high inflation would be particularly sensitive to inflation rates when making intertemporal choices; i.e. they may be more likely to take into consideration the effect of inflation on future rewards. This study compares intertemporal choices of participants from countries with dramatically different histories of inflation: Argentina and Britain. Participants completed a delay discounting task under two inflation rate conditions (2% and 20%, between subjects). We found that people discounted future rewards more steeply under the 20% inflation rate condition than under the 2% condition. Participants from Argentina, the country with much higher current and historical inflation rates, discounted future rewards more steeply in both inflation rate conditions than participants from the UK. However, Argentines were not more sensitive to inflation rates than British people.

Key words: Delay discounting; Intertemporal choice; Argentina; UK; Inflation rate.
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1. Introduction

Other things being equal, people generally prefer to receive rewards sooner rather than later. As such, we are often willing to forgo a larger reward in the future for a smaller reward available immediately: for example, preferring to take £95 today over £100 in a year, or to smoke a cigarette now at the expense of long-term good health. The extent to which people prefer more immediate rewards is quantified in the study of *delay discounting*, which captures the way in which the value of a reward declines as the delay until its receipt increases.

Delay discounting is a widespread phenomenon, seen across multiple reward types, including food (e.g., Rasmussen, Lawyer, & Reilly, 2010), health (e.g., Chapman & Elstein, 1995), cigarettes (e.g., Bickel, Odum, & Madden, 1999), and illicit drugs (e.g., Madden, Petry, Badger, & Bickel, 1997), is seen for both gains and losses (e.g., Estle, Green, Myerson, & Holt, 2006), and is observed in both humans and non-human animals (Jimura, Myerson, Hilgard, Braver, & Green, 2009). Although delay discounting is relatively consistent within an individual and experimental procedure (Simpson & Vuchinich, 2000; Beck & Triplett, 2009), discounting is highly context-specific (see Lempert & Phelps, 2016, for a review), and varies substantially across individuals.

1.2 Rationality and discounting

High rates of delay discounting are often used as illustrations of human irrationality, adding to the many suboptimal heuristics and biases catalogued in decision making research. Discounting is often framed in terms of temporal myopia (Kirby & Maraković, 1995), self-control failure (Madden et al., 1997) or impulsivity (Alessi & Petry, 2003), supported in part by the correlation between high delay discounting rates and other impulsive behaviours such as smoking, overeating, infidelity, and illicit drug use (see, e.g., Reimers, Maylor, Stewart, &

Chater, 2009). At the extreme, any preference for a smaller-sooner reward over a larger-later reward is treated as an impulsive choice.

However, there are several reasons why choosing a smaller-sooner reward might be a normative, or at least non-impulsive, choice. Choosing to wait for a larger sum of money has an opportunity cost – there may be opportunities in the intervening time to spend a smaller-sooner sum of money that has a high hedonic value per unit cost (see Read, 2004; also Zauberman & Lynch, 2005, for a similar argument). For example, an individual who chooses to wait for a sum of money rather than take it immediately would miss out on the opportunity in the intervening time to purchase a desired commodity if it was temporarily dramatically reduced in price, or take up a lucrative, time limited, investment opportunity.

Similarly, future gains may be less certain than immediate gains, either in the hedonic value they have to an individual (at the extreme, an individual may not be alive to experience the delayed outcome at all; see Chabris, Laibson, & Schuldt, 2010, for discussion of mortality risk in discounting) or in the certainty of receipt – the money is less trusted to come through in the more distant future (e.g., Patak & Reynolds, 2007).

Most concretely, there is the effect of inflation, which erodes the value of a fixed sum of money (see Urminsky & Zauberman, 2014). These effects can be dramatic: A fixed £1,000 in 10 years' time will be worth around one tenth as much in a high-inflation (30%) environment as in a low-inflation (3%) environment.

Most discussions of delay discounting ignore the effects of inflation. There is some justification for this: Inflation cannot – at the relatively low rates seen in developed countries over recent decades – account for the comparatively high rates of discounting observed in the literature. Nor does discounting disappear completely when factors like inflation are controlled (see Frederick, Loewenstein, & O'Donoghue, 2002, for a review). Nonetheless, decision makers should normatively take inflation into account when making intertemporal

choices. As Frederick et al. (2002) noted, an individual's experiences and expectations with regard to inflation should influence their intertemporal decisions.

Furthermore, most of the discussion about inflation in intertemporal choice has assumed rates around those seen recently in developed countries. Many other countries have had much higher inflation rates: For example, Venezuela's inflation rate in 2016 was around 800%, and in periods of hyperinflation (such as Zimbabwe in 2008) countries have experienced periods with inflation rates of 100% *per day*. If a rational agent expected the latter inflation rate to continue, they should non-impulsively prefer to take Z$1 today rather than Z$300 million in a month's time.

Whether inflation actually does affect people's discounting of rewards is a more open question. Ostaszewski, Green, and Myerson (1998) examined the effect of inflation on the subjective value of delayed and probabilistic rewards. They combined a typical discounting task, in which participants from Poland had to choose between an immediate and a delayed reward, which were available in two currencies that differed in their associations with inflation. The authors found that the subjective value of a delayed reward was greater when its amount was specified in a low inflation currency (US dollars) rather than in a high inflation currency (old Polish zlotys). Although it is impossible to control for all non-inflationary differences in the perception of the currencies, the results suggest that previous experience of inflation might have increased discounting.

In an experimental study, Kawashima (2006) created an artificial inflation rate across a series of trials by varying the purchasing power of a financial reward. Participants took part in three experimental conditions: inflationary, zero-inflationary, and deflationary. The author found that the delayed reward in the inflationary scenario was discounted more steeply than in the zero-inflationary and deflationary scenarios, suggesting a sensitivity to inflation.

Additionally, Takahashi, Masataka, Malaivijitnond, and Wongsiri, (2008) showed that among Thai participants, discounting of hypothetical money was steeper than that for hypothetical rice during a time of economic turbulence. They noted that generally food is discounted more than money, and that the opposite pattern of valuations they found might have been due to uncertainty about the future value of monetary outcomes.

One way of examining the effects of experience with and expectation of inflation would be to compare discounting in countries where inflation is and has historically been high with that where inflation is and has been lower. A small number of cross-cultural studies of discounting have been conducted (e.g., Du, Green, & Myerson, 2002; Kim, Sung, & McClure, 2012), often showing differences in discount rates. Another approach has been to examine time preferences at the national level by analysing the temporal properties of the most frequent web searches (e.g., Noguchi, Stewart, Olivola, Moat, & Preis, 2014; Preis, Moat, Stanley, & Bishop, 2012). These studies revealed a relationship between time perspective and gross domestic product (GDP), but did not directly examine associations with inflation rates. One notable exception is a study by Wang, Rieger, and Hens (2016), who conducted a discounting task in 53 countries. The authors found substantial differences in time preferences across countries, but no association between either current or recent maximum inflation rates and discounting.

2. The present study

We hypothesise that experience with inflation affects intertemporal choices in two distinct ways. First, people in countries with historically higher rates of inflation may discount future rewards more. More subtly, it could be that experience with high levels of inflation makes people more sensitive to inflation rates when making intertemporal choices; that is, they take more account of the effects of inflation when valuing future rewards. In particular, one might expect individuals from countries with low levels of inflation to ignore or underweight the

long-term effects of inflation on purchasing power compared to those from countries with direct – costly – experience of the erosion of value from inflation.

We examined these two possibilities by comparing delay discounting choices among samples from Argentina and the UK in two different scenarios – one with an annual inflation rate of 2% and one with an annual inflation rate of 20%. Argentina's annual inflation rate for 2016 was 40.3% (IPC Congreso, 2017) while the UK's annual inflation rate for the same year was 1.6% (Office for National Statistics, 2016). The selection of these two countries allowed us to test how people behave when they face a familiar inflation rate and a less familiar one. For instance, a 2% annual inflation rate is unfamiliar to Argentines, who have experienced inflation rates varying between 25% and 40% in the last 15 years. Similarly, an annual inflation rate of 20% is unfamiliar to UK residents as it exceeds by far the inflation rates that have been seen in the UK in the last 15 years, with a peak inflation rate of 4.2% in 2011.

We further examined how people's knowledge of historical inflation rates in their home country and their ability to account for the impact of compound interest on the future values of goods are related to the discounting of future rewards. We argue that people with lower inflation literacy discount future rewards more steeply than people with higher literacy.

3. Method

3.1 Participants

Participants from Argentina (n = 219) were recruited through OH Panel!, an Argentine crowdsourcing platform with a pool of participants who take part in surveys, tasks or experiments. Each Argentine participant was paid US$ 1.50 per complete task. Participants from the UK (n = 174) were recruited through Prolific Academic, a UK-based platform for participant recruitment, and were paid £1.07 per complete task. The task was offered to people who were at least 18 years old, enrolled in the participant pool of each platform, and who were nationals of the respective country. Those who consented to take part in the

experiment were presented with an attention check before the discounting task which was meant to verify that participants read all questions carefully. The attention check consisted of a question about favourite sports which included several answer categories. However, the question's preamble instructed participants to click on the page title instead of selecting a response in order to proceed with the experiment. Participants who failed the attention check (i.e., selected an answer category instead of clicking on the title) were redirected to the end of the questionnaire before answering any questions. In addition, we included several recall questions at the end of the task to test whether participants remembered the description of the hypothetical country and therefore probably took it into account while completing the discounting task. Most importantly, participants were asked about the country's inflation rate, its population and which situation best described the country (high employment and low corruption, among other options). Of the 492 participants who completed the survey, 99 answered at least one of these questions incorrectly and were excluded from the final sample (Argentina: 60 and UK: 39). However, at the end of the study, we re-ran our analysis with the full sample (including these 99 participants) and found the same substantive results. Unsurprisingly, effects were weaker with the full sample and the coefficient for the inflation rate condition was no longer significant (the complete data set is archived on the Open Science Framework, https://osf.io/6j8n9/).

The final sample consists of 393 participants, 219 from Argentina and 174 from the UK. Of these 393 participants, 146 are male and 247 are female (Argentine sample: 38% male; UK sample: 36% male) with ages ranging from 18 to 80 (Argentina Mean = 45.90, SD = 12.81; UK Mean = 42.20, SD = 13.58).

3.2 Design and materials

Participants were presented with a scenario in which they had inherited an investment in an unnamed foreign country and had to choose whether to cash in the investment immediately or

wait until they could obtain more money. In order to provide some context, several facts about the hypothetical country were shown: Filler information about the population, levels of employment and corruption, and our main variable of interest, the inflation rate, along with a description of whether it was considered low or high. While the irrelevant facts (population, employment, etc.) were the same in both conditions, the inflation rate was manipulated: In one between-subjects condition the rate was low (2%) and in the other it was high (20%). Participants from both Argentina and the UK were randomly assigned to one of the inflation conditions (Argentina: n=120 Low, n=99 High; UK: n=94 Low, n=80 High). A fictitious currency was used, to avoid participants' use of existing inflationary knowledge, and a point exchange rate to US dollars was given to allow evaluation of magnitude. Perceptions of uncertainty about the receipt of the money in the future were reduced by informing participants that the investment was safe because it was backed by the government of the country along with several international agreements. Participants were then invited to make a series of binary choices between hypothetical amounts of money in a discounting task, one available immediately and the other one after a delay of varying length, to estimate the immediate value of a delayed amount of 10,000 units of a hypothetical currency across four delays: 1 month, 6 months, 1 year and 5 years.

Two measures of inflation literacy were constructed based on seven separate questions. The variable 'Knowledge of compound interest' is the sum of correct answers to four different questions about the calculation of goods' prices in an inflationary context. A value of one was assigned to each question if participants answered it correctly, treating rounding errors as correct, and zero otherwise. The variable 'Knowledge of previous inflation rates' is the sum of correct answers to three questions. As the correct answers for these questions differed by country and the magnitude of the correct answers was substantially different, a direct comparison of scores was not meaningful. Therefore, we calculated the

distance between the correct answer and each participant's response and the absolute value of the whole measure per country. We ranked scores within each country and centred the mean of each country distribution to zero to counterbalance the effect of sample differences. The exact information participants read and the seven questions used to construct these two measures can be found in the Supplementary Materials (section S1).

Finally, participants were asked additional questions including their gender, age, highest level of education, nationality, perception about their income and the recall questions previously described. Descriptive statistics of the variables included in the regressions are shown in Table 1.

Table 1: Descriptive statistics and definitions of variables by country

	Argentina			UK			
Variable	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Definition**
Male	0.38 (0.49)	0	1	0.36 (0.48)	0	1	Gender dummy (1 = male)
Age	45.90 (12.81)	19	80	42.20 (13.58)	18	80	Age of respondent at time of survey in years.
Level of Education	3.37 (1.13)	1	5	3.28 (1.40)	1	5	Level of education 1 to 5 (1= Secondary school/some high school; 2= Sixth form/completed high school; 3= Incomplete university; 4= Completed university; 5= Postgraduate qualification).
Income ladder	5.55 (1.31)	2	9	5.15 (1.59)	1	10	Imagine a staircase with 10 steps where the poorest people in your country are on the first step and the richest on the tenth step. Where would you put yourself on this staircase?
Knowledge of compound interest	1.79 (1.33)	0	4	2.05 (1.07)	0	4	Level of knowledge of calculation of prices of goods in an inflationary situation. A higher value indicates better knowledge. (Possible range 0-4).
Knowledge of previous inflation rates	0 (20.61)	-48.57	39.43	0 (13.3)	-22.94	40.06	Level of knowledge of previous inflation rates. A higher number denotes better knowledge.

3.3 Procedure

The study was coded in Adobe Flash (see Reimers & Stewart, 2015) and run online. Two versions of the experiment were used: The Argentine version was in Spanish and the UK version in English, with the translation of the English version into Spanish conducted by the first author, a native Argentinian Spanish speaker. The Spanish version was also back-translated into English by a bilingual speaker; we did not find significant differences between the translations. The experiments were identical in all other respects. Participants received an email from the panel to which they were subscribed and clicked a link to a URL on the researchers' servers where they completed the study. For the delay discounting task, we implemented a staircase procedure (e.g., Du et al., 2002): the immediate amount for subsequent choices was adjusted based on earlier choices. The delayed reward was shown on the right side of the screen and the smaller, immediate reward on the left side. For the first binary choice at a given delay, participants chose between a delayed 10,000 units (the larger-later option) or an immediate 5,000 units (the smaller-sooner option), i.e., half of the delayed reward. To obtain the present subjective value of the delayed reward the amounts shown were adjusted in each iteration as follows: if a participant chose the larger-later option in the first stage, the smaller-sooner reward was increased by half of the difference between the initial immediate and delayed reward amounts; conversely if the smaller-sooner option was chosen, the smaller sooner value decreased the same way on the next trial. This procedure, with six iterations, converged on the immediate value of the larger-later outcome. This subjective value, representing the best estimate of the immediate value of the delayed amount, was recorded for each of the four delays, resulting in four measures per participant.

3.4 Analytical methods

The procedure used to assess differences in individual discounting rates is the calculation of the area under the discounting function (Myerson, Green, & Warusawitharana, 2001). The

advantage of this method is that it is theoretically neutral because the area under the curve (AUC) is calculated from the observed data points (the empirical discounting function) instead of a theoretical discounting function fitted to the data. The area under the curve can vary between 0 (steepest discounting) and 1 (no discounting); therefore, a smaller AUC implies steeper discounting.

We analysed differences in individuals' discounting behaviour using ordinary least squares regressions (OLS) with the AUC as the dependent variable and indicator variables for the country and inflation condition as predictors. Our model also accounts for possible differences in sample composition between the two countries by including socio-demographic variables that have in the past been associated with discount rates, namely, age, gender, education and perception of income, measured by the income ladder question, (e.g., Green, Myerson, & Ostaszewski, 1999; Reimers et al., 2009).

4. Results

One potential problem with discounting tasks is that the resulting data may be non-systematic. Although the analysis that follows does not exclude any non-systematic responses, a similar analysis that does gives almost identical results. Researchers have proposed various criteria by which such data can be identified and subsequently excluded from the analysis, for instance, based on the variance accounted for by the model (e.g., Myerson & Green, 1995; Reynolds, Richards, & de Wit, 2006) or other criteria (e.g., Johnson & Bickel, 2008). To check that our results are not biased due to non-systematic data, we checked whether responses met any of the following two exclusion criteria: 1. Starting from the second delay, the subjective value shows an increase of more than 20% of the delayed reward (i.e., 2000) in relation to the preceding value (first exclusion criterion suggested by Johnson and Bickel, 2008), and 2. The subjective value of the last delay (i.e., 5 years) is greater than the subjective value of the first delay (i.e., 1 month). Discounting choices that

followed either one or both of these criteria were excluded from the data set and the analysis was re-run. 23 cases were deleted across both samples, most of them due to the second criterion and because the participants showed no sensitivity to delay, namely, no discounting. The regression models based on the reduced sample can be found in the Supplementary Materials section (section S2). Our results are therefore not driven by potentially non-systematic choices.

4.1 The shape of the discounting function

Much of the literature on delay discounting in financial decisions has examined the nature of the relationship between a reward's delay and its perceived value. Normatively, people might be expected to show exponential discounting. However, when participants evaluate or choose between options at varying delays, their choices, both at the individual and aggregate level, tend to be better approximated by a hyperbolic function linking delay and value (e.g., Kirby & Herrnstein, 1995; Myerson & Green, 1995). Similarly, in the present analysis, a hyperbolic model fits the data better than an exponential model; both at the group level and in a large number of participants. (Equations for each type of discounting as well as the analysis of data fit can be found in the Supplementary Materials, section S3).

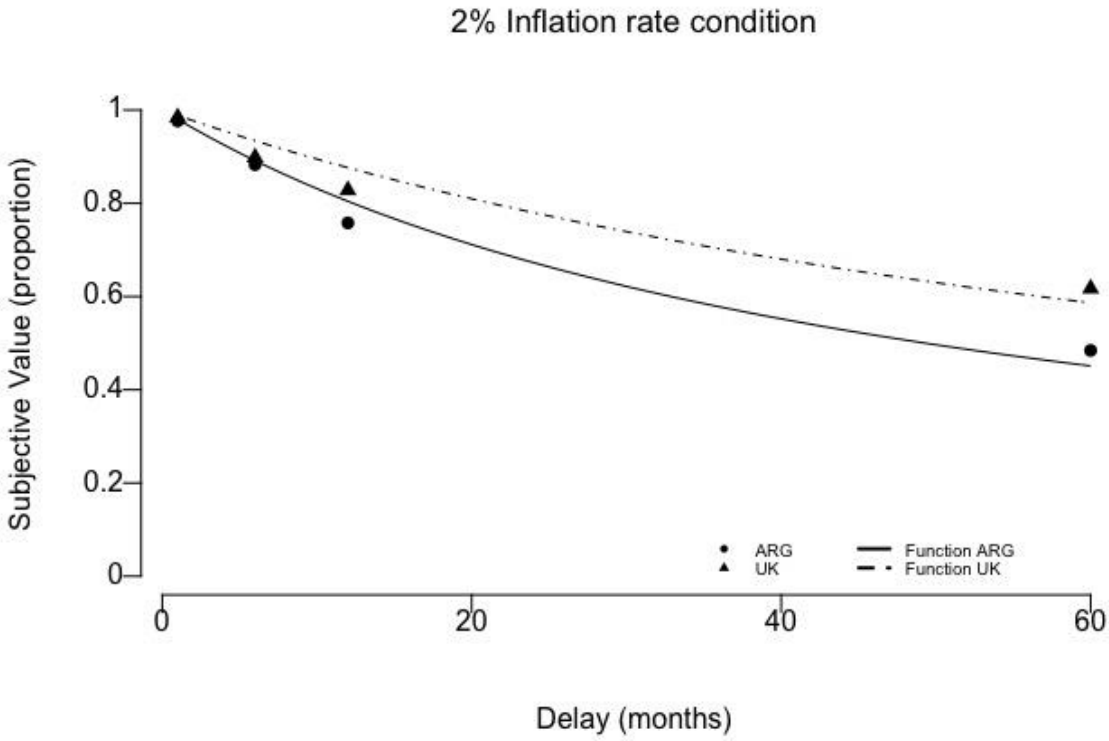
4.2 Discounting results

We employed a process which bisects the possible range of the immediate subjective value of a given delayed reward in each iteration. This process yields the smallest immediate value that is preferred over the delayed outcome and the largest immediate value that is rejected for each participant-delay-amount combination. The indifference point is – as is standard with these procedures – taken as the mean of these two values. For example, if a participant chooses "£200 in a month" over "£50 now", but prefers "£60 now" over "£200 in a month", their indifference point for that delayed outcome is £55. The AUC was then calculated for each participant using these points. The values in Figures 1 and 2 are the means across all

participants of these individual indifference points. The curves represent the best fit of the data to the hyperbolic function. Thus, these calculations are relatively independent of theory.

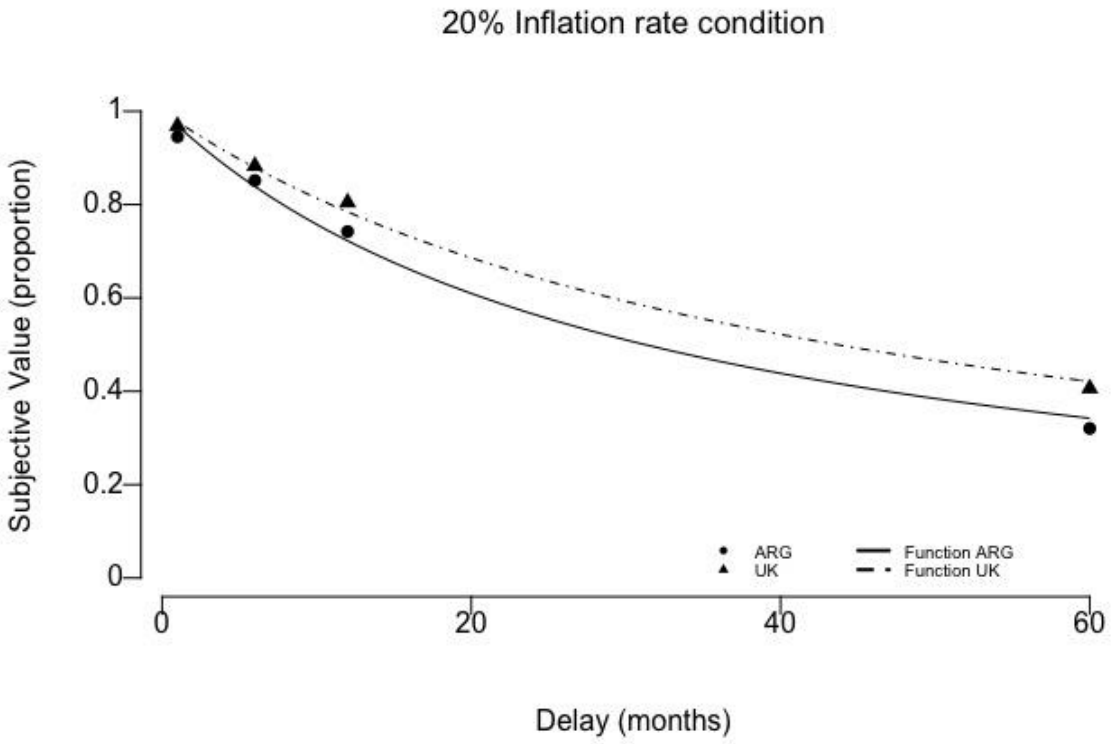
More specifically, Figures 1 and 2 show how participants from Argentina and the UK discount future rewards in the two inflation rate conditions. Figure 1 shows the median subjective values of the delayed reward for each delay for Argentine (circles) and British (triangles) participants in the low inflation condition (2%). Figure 2 shows the same type of information for the high inflation condition (20%).

Figure 1: Median subjective values of the reward for each country as a function of delay in the low inflation rate condition (2%).



The subjective value of the reward is presented as a proportion of its nominal amount. Curves represent the best fit to the hyperbolic function V=A/(1 + kD) where V is the subjective value of the delayed reward, A is the absolute value of the delayed reward, D denotes the delay until receipt of the delayed reward, and k is the discounting parameter.

Figure 2: Median subjective values of the reward for each country as a function of delay in the high inflation rate condition (20%).



The subjective value of the reward is presented as a proportion of its nominal amount. Curves represent the best fit to the hyperbolic function V=A/(1 + kD) where V is the subjective value of the delayed reward, A is the absolute value of the delayed reward, D denotes the delay until receipt of the delayed reward, and k is the discounting parameter.

We tested our hypotheses employing ordinary least squares regressions (Table 2). This approach allowed us to account for potential sample differences by including socio-demographic variables as predictors in the regression. We ran two different regression models which use the Area Under the Curve as the dependent variable. As described above, this method employs people's actual responses and avoids fitting a mathematical function to the data. In the first model, we tested the relationship between the Area Under the Curve and participants' country of residence, the inflation rate condition, the interaction between these two variables, gender, age, income ladder and level of education. The second regression model adds to the first model two measures of inflation literacy (Table 2, column 2). The first

model (Table 2, column 1) suggests that Argentine participants discount future rewards more steeply than participants from the UK under both inflation rate conditions, as reflected in the significant, positive coefficient for the UK country indicator variable (b=0.110, p=.002). In addition, participants are, on average, sensitive to inflation rates: they discount future rewards more steeply under the 20% than under the 2% inflation rate condition, as shown by the positive and significant coefficient of the 2%-inflation rate indicator variable (b=0.065, p=.04). The model does not show significant associations between the AUC and any of the socio-demographic control variables. We further do not find evidence that sensitivity to inflation rates varies by country; the interaction term between country of residence and inflation rate condition is not significant in our model (b=-0.035, p=.46). This finding suggests that people who have experienced high inflation are not more sensitive to inflation rates than those without such experience. We do not find any significant associations between the socio-demographic variables and the AUC. However, in the standard model (Table 2, model 1), the associations regarding age, education and income were all in the direction seen in previous research (i.e., older, richer, better educated people had higher AUC), but did not reach statistical significance. It is possible that these effects are small and would have been significant in a larger sample.

We included two measures of inflation literacy in a second model in order to assess whether responses in the discounting task were affected by the participant's knowledge of compound interest and historic inflation rates in their home country (Table 2, column 2). As before, the results indicate that British participants show shallower discounting than Argentine participants, even after controlling for inflation literacy (b=0.104, p=0.003). Participants in general discount more under the 20% inflation condition than under the 2%, showing sensitivity to the inflation rate (b=0.065, p=.04). Participants' knowledge of compound interest is significantly positively associated with the Area Under the Curve

(b=0.021, p=.04), which suggests that people with better knowledge discount future rewards less steeply than people with poorer knowledge. In contrast, knowledge of previous inflation rates in one's home country is significantly negatively associated with the AUC (b=-0.002, p=.02). However, the magnitude of this effect is quite small as the coefficient is close to zero. The coefficient for the country of residence indicator variable remains significant after adding measures of inflation literacy to the model, suggesting that differences in discounting behaviour across countries may be more related to country differences than to inflation literacy.

Table 2: Ordinary least squares regressions for the Area Under the Curve (AUC)

	Dependent variable: Area Under the Curve	
	(1)	(2)
Country of residence – UK *(Ref.: Argentina)*	0.110**	0.104**
	(0.035)	(0.035)
Inflation rate condition - 2% *(Ref.: 20%)*	0.065*	0.065*
	(0.032)	(0.031)
Gender - Male	0.048	0.019
	(0.025)	(0.026)
Age	0.001	0.001
	(0.001)	(0.001)
Level of education	0.003	-0.005
	(0.010)	(0.010)
Income ladder	0.002	-0.0002
	(0.008)	(0.008)
Country of residence - UK*Inflation rate condition - 2%	-0.035	-0.038
	(0.048)	(0.047)
Knowledge of compound interest	-	0.021*
		(0.010)
Knowledge of previous inflation rates	-	-0.002*
		(0.001)
Constant	0.459***	0.462***
	(0.069)	(0.071)
Observations	393	393
R^2	0.058	0.089

Adjusted R^2	0.041	0.067
Residual Std. Error	0.235 (df = 385)	0.231 (df = 383)
F Statistic	3.403^{***} (df = 7; 385)	4.151^{***} (df = 9; 383)

Note: *p<0.05; **p<0.01; ***p<0.001.

Additionally, we investigated whether discounting differs from the inflation rate presented in the experiment. Employing a t-test, we compared the AUC for both countries in both inflation rate conditions with the AUC which corresponds to the inflation rates presented in the experiment, 20% and 2%. We found that in the low inflation condition AUCs of both countries are significantly smaller (i.e., higher discounting) than the AUCs corresponding to the treatment inflation rate of 2%, [$t_{Arg}(119) = 15$, $p < .001$; $t_{UK}(93) = 11$, $p < .001$]. In the high inflation condition, both AUCs are numerically smaller than the AUC corresponding to the treatment inflation rate of 20%, although this difference is only significant for Argentine participants [$t_{Arg}(98) = 4.35$, $p<.001$; $t_{UK}(79) = 0.21$, $p=.83$].

4.3 Additional analyses

We performed additional analyses in order to confirm the robustness of the results (the regression tables can be found in the Supplementary Materials section). We repeated the main regression analysis including interaction terms between treatment effects and each of the socio-demographic variables. The only additional significant coefficients can be found for the interaction between age and both country of residence (Table S4.1, model 2) and inflation rate condition (Table S4.2, model 2). These results suggest that the AUC increases more with age in the UK than in Argentina (i.e., older people discount less). However, the main effect of age is not significant, suggesting that there is actually no association between age and AUC in Argentina, the reference category. The significant coefficient for the interaction term between inflation rate condition and age (Table S4.2, model 2) implies a positive association between AUC and age in the 2% condition (i.e. older people discount less), but this is not the

case in the 20% condition as the coefficient for age is not significant. These results confirm previously found age effects (e.g., Reimers, et al, 2009) and suggest that our UK data are sensible. In addition, the results indicate that older people in Argentina do not show a lower discounting rate as is usually found in their age group. This may be due to their likely earlier experience with hyperinflation.

In addition, we explored the role of people's experience with inflation assuming that older people are more likely to have more experience with high inflation than younger people. We created two groups for each country based on each participant's age during periods of higher inflation in their country (assuming that participants had to be at least 16 years old to be personally significantly affected during periods of high inflation). For Argentina, the high inflation group contains observations for people who were at least 16 years old in 1989, the year of hyperinflation. They were thus at least 43 years old in 2016, the year of data collection. For the UK, the high inflation group contains observations for people who were at least 16 years old in 1975, the year with the highest recent inflation rate in the UK. These participants were at least 57 years old in 2016. We repeated the main regression analysis with interaction terms between these newly created age groups (proxies for experience with high inflation) and the inflation rate condition. We did not find a significant coefficient for this interaction in any of the two country samples (Table S5). This finding confirms that people with experience with higher inflation are not necessarily more sensitive to inflation rates than people without such experience.

5. Discussion

The present study used a hypothetical delay discounting procedure to examine the effect of inflation rate on discounting. Participants completed –between subjects – sets of binary discounting choices in scenarios with two annual inflation rates – 2% and 20%. We examined the effect of this manipulation in participants from Argentina (who most likely had direct

experience of high inflation rates as they live in a high inflationary context) and the UK (who most likely did not as they live in a low inflationary context).

We formulated three predictions about the effect of experience with inflation on individual discount rates. The first was that discount rates would be higher in scenarios with high inflation than in low inflation scenarios. This is what we found, and this result is in line with Kawashima's (2006) findings suggesting that high inflation is associated with steeper discounting.

The second prediction was that people who had the experience of high inflation would show higher discount rates. As such, we predicted that our Argentine sample would show higher rates of discounting than our UK sample. This was what we found. This result is congruent with Ostaszewski, et al.'s (1998) finding that delay discounting was higher in a currency with a history of high inflation than a currency with a history of low inflation. It also fits with findings from Takahashi, et al. (2008), who found that in a turbulent economic scenario food is, in general, discounted more than money. The reason for this reversal might have been the uncertainty about the future value of monetary outcomes.

As with other cross-cultural studies (e.g., Du, et al., 2002; Wang, et al., 2016), this conclusion can only be tentative. We attempted to recruit participants with a similar demographic distribution in the UK and Argentine samples, and to include demographics in our analyses. That said, although we accounted for a number of socio-demographic variables and participants' inflation literacy, unobserved differences between the samples from the two countries may remain. Future studies should include additional measures to better understand sample differences which may be related to individual sensitivity to inflation rates. For instance, the home country's political and economic stability, individual preferences for gambling or tolerance for risk, more detailed measures of education (type and area of study; e.g., finance versus non-finance-related studies), as well as differences in relative and

absolute income. However, such additional measures would require careful interpretation. For example, we decided to include a relative rather than an absolute measure of income in our study because although absolute income is almost certainly lower among our Argentine participants compared to our British participants, costs of living are also generally lower in Argentina.

The third prediction was that people with experience of high inflation would have a better grasp of the way in which high inflation rates erode the value of future rewards and would show a greater sensitivity to the inflation rate in the scenarios we used. We, therefore, predicted that the difference in discount rates for 2% and 20% inflation rate scenarios would be greater for Argentine participants than for UK participants. We did not find this: participants from the two countries showed similar – relatively weak – sensitivity to inflation rates in our scenarios.

5.1 Implications

Overall, our findings suggest that people are sensitive to inflation rate in discounting tasks, but that they are not sensitive enough: Objectively, a sum of money available in five years would be able to buy twice as much in a 2% inflation condition than in a 20% condition, yet participants valued 5-year-delayed rewards only around 1.5 times as much in the 2% condition than the 20% condition (see Figures 1 & 2). Further, we found that living in a country with current and historic high rates of inflation did not make people react more strongly to higher inflation rates – if anything, experience with high inflation rates led to higher overall discounting rather than increased sensitivity to inflation in a discounting scenario. Due to their experience with higher inflation rates, participants from Argentina may be more used to dealing with inflation. For instance, a 20% annual inflation rate may be familiar to Argentine people and lead to less sensitivity to changes in inflation rates. Of course, the higher overall discounting need not be irrational. Although our study informed

participants about the current inflation rate, it did not (and, of course, could not) state what the inflation rate in the future would be. As such, participants from Argentina might have made predictions that inflation would be higher over coming years than those from the UK, and so discount future outcome accordingly.

We found that people with better ability to calculate compound interest discount future rewards less steeply than people with less ability. This was a counterintuitive finding. We predicted that those with better ability would be more able to overcome people's natural propensity to underestimate the effects of compounding, and so would see the true impact of inflation on future value. As such, we predicted that they would show higher discounting, particularly in the high-inflation scenario. However, it can be related to the association between cognitive ability and discounting behaviour: Frederick (2005) found that people who scored higher on the Cognitive Reflection Test (i.e., people who tend to engage in reflective, deliberative and conscious thinking) devalue or discount future rewards less than people who obtained a lower score. Similarly, IQ and cognitive skills are associated with lower rates of discounting (see, e.g., Burks, Carpenter, Goette, & Rustichini, 2009; de Wit, Flory, Acheson, McCloskey, & Manuck, 2007). Presumably, there is a rate of inflation at which more numerate participants would discount more highly than less numerate participants.

We also included a question which tested people's knowledge and memory of previous inflation rates in their home country. In this case, although the effect is modest, people with better knowledge discount future rewards more steeply than people with poorer knowledge. Previous research (e.g., Senecal, Wang, Thompson, & Kable, 2012) has suggested that high individual's discount rates can be due to lack of knowledge of the normative strategy on how to deal with interest rates and future rewards.

Finally, the discounting behaviour we observe among our participants reflects that of participants in typical discounting studies: the subjective values decrease as delay increases

(Benzion, Rapoport & Yagil, 1989; Thaler, 1981) and furthermore, the rate of discounting decreases with increasing delay, as shown by a better fit to a hyperbolic versus and exponential function. In the high-inflation condition, discounting was approximately that normatively predicted from compensating for inflation. However, in the low-inflation condition, discounting was much higher than normatively predicted from inflation. This finding is in line with a Frederick et al.'s (2002) study which suggests that individual's discount rates are significantly higher that market interest rates.

5.2 Limitations and future work

One potential limitation of this study was that participants were not incentivised to report true preferences, using hypothetical rewards. Although this is the approach taken in other inflation-related research (e.g., Ostaszewski et al., 1998; Takahashi et al., 2007), it is possible that participants would have responded differently with real outcomes.

We do not think that this had a substantial effect on our results. There are few differences in delay discounting or real and hypothetical rewards (e.g., Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003), and participants showed patterns of discounting – such as the hyperbolic shape of the discounting function, and overall rate of discounting – that were consistent with both incentivised and non-incentivised previous research. It is, of course, hard to use real outcomes in discounting choice designs around inflation without complicating the task by using artificial monetary exchange rates. However, it might be possible to use a multi-round procedure where participants' future gains lose value across rounds (see Kawashima, 2006) to simulate inflation and explore differences in these scenarios. This would give a different type of sensitivity to inflation, but one that was rather distant from the delay discounting literature.

Another limitation is that we cannot assess to what extent participants took into account the potential effect of uncovered interest rate parity (UIP), which is related to an

uncovered risk in changes in foreign exchange rates. A higher inflation rate may suggest to participants a higher loss on the exchange rate as the rewards in our study are expressed in a foreign currency. There is a risk in waiting to cash in rewards because of possible changes in currency exchange rates, even more so in the presence of inflation. However, although we cannot know for certain whether participants took the UIP into consideration, we believe that only participants with a deep knowledge of finance or economics were likely to do so. Studies that use payoffs in the currency of participants' home country do not encounter this potential limitation (e.g., Wang et al., 2016). However, we believe that a hypothetical currency was more appropriate for our scenarios because participants are likely to have certain expectations and biases with regards to inflation for specific currencies.

We also note that the scenarios we used underplayed the salience of inflationary information. We deliberately did not emphasise the inflation rate, but included it along with other details about the scenario as we did not want the manipulation to be transparent to participants. This may in part explain why participants' sensitivity to inflation rate was relatively weak. It is possible that when participants are more explicitly cued to take into account inflation, larger effects of inflation and other macroeconomic country characteristics might emerge. However, our results suggest that participants from Argentina do not automatically attend to and use inflation information more than those from the UK.

6. Conclusion

One way in which high rates of discounting are explained normatively is that people compensate for anticipated high rates of future inflation, based on their previous experience. We noted that outside the recent experiences of developed countries, inflation rates are high enough to justify very high rates of discounting. However, our findings suggest that participants are normatively suboptimal: They take into account inflation, but not enough,

and experience with high inflation rates does not lead to improved calibration to inflation rates in discounting tasks.

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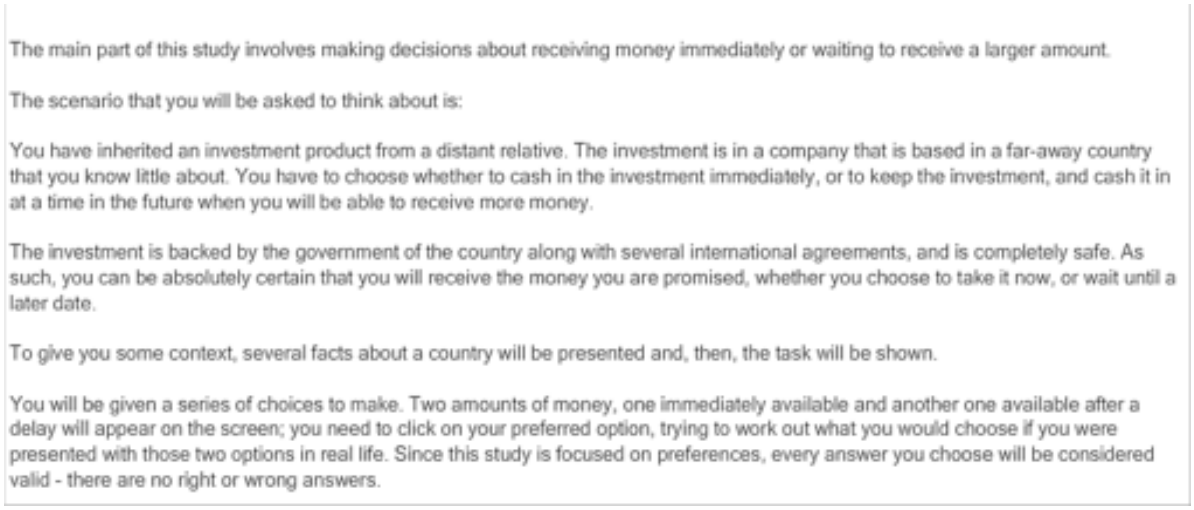
Supplementary Materials

S1. Instructions for the experiment

Screen 1: Introduction to the study


The main part of this study involves making decisions about receiving money immediately or waiting to receive a larger amount.

The scenario that you will be asked to think about is:

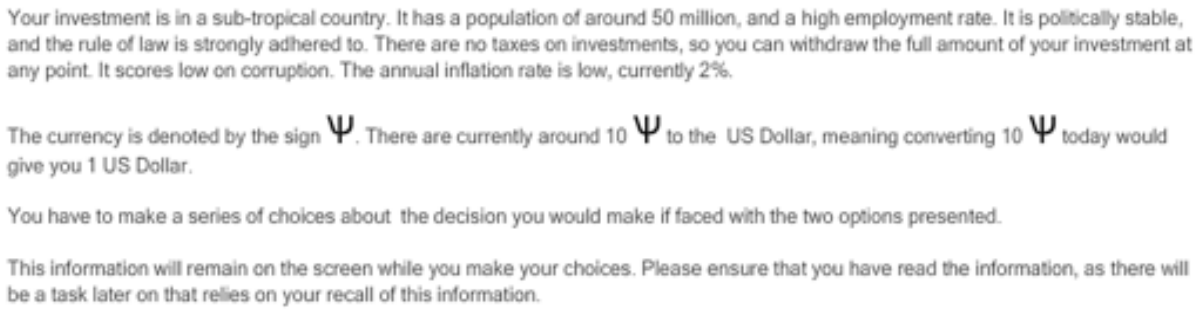
You have inherited an investment product from a distant relative. The investment is in a company that is based in a far-away country that you know little about. You have to choose whether to cash in the investment immediately, or to keep the investment, and cash it in at a time in the future when you will be able to receive more money.

The investment is backed by the government of the country along with several international agreements, and is completely safe. As such, you can be absolutely certain that you will receive the money you are promised, whether you choose to take it now, or wait until a later date.

To give you some context, several facts about a country will be presented and, then, the task will be shown.

You will be given a series of choices to make. Two amounts of money, one immediately available and another one available after a delay will appear on the screen; you need to click on your preferred option, trying to work out what you would choose if you were presented with those two options in real life. Since this study is focused on preferences, every answer you choose will be considered valid - there are no right or wrong answers.

Screen 2: Context of the experiment

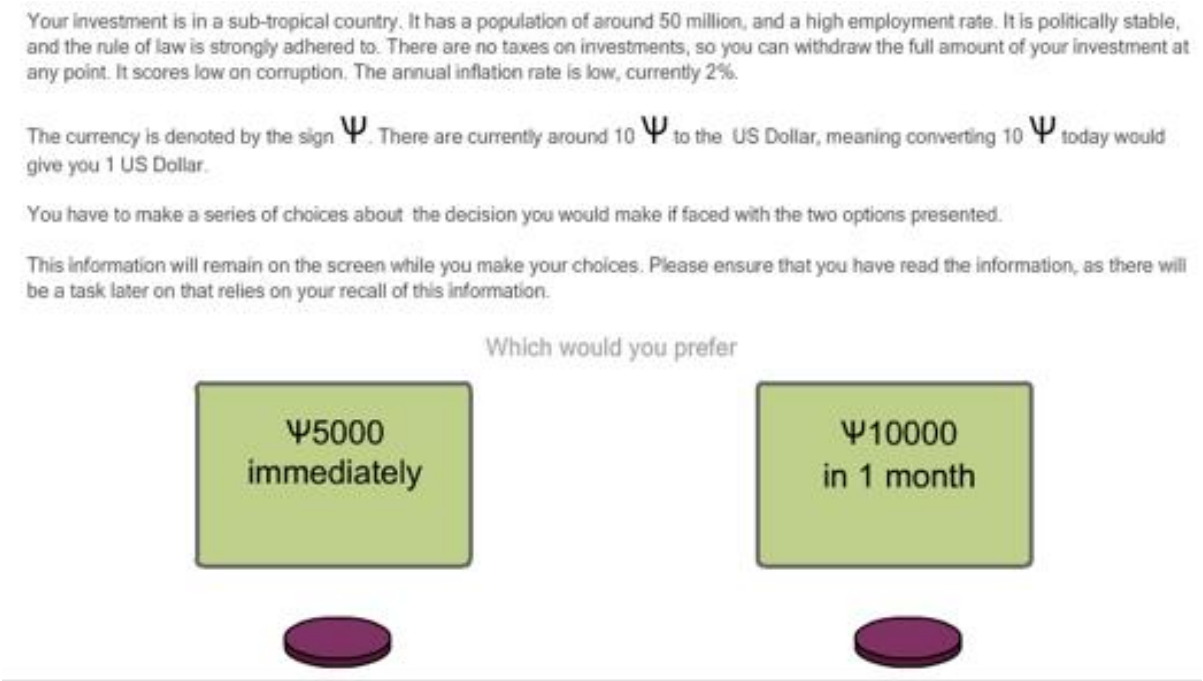

Your investment is in a sub-tropical country. It has a population of around 50 million, and a high employment rate. It is politically stable, and the rule of law is strongly adhered to. There are no taxes on investments, so you can withdraw the full amount of your investment at any point. It scores low on corruption. The annual inflation rate is low, currently 2%.

The currency is denoted by the sign Ψ. There are currently around 10 Ψ to the US Dollar, meaning converting 10 Ψ today would give you 1 US Dollar.

You have to make a series of choices about the decision you would make if faced with the two options presented.

This information will remain on the screen while you make your choices. Please ensure that you have read the information, as there will be a task later on that relies on your recall of this information.

Screen 3: First screen with the different amounts of money



Creation of inflation literacy measures

The measure *'Level of knowledge of previous inflation rates'* is composed of three questions:

1) To the best of your knowledge, what was the highest annual rate of inflation that your country experienced during the last 30 years?

   Correct answer Argentina: 3079%

   Correct answer UK: 7.53%

2) To the best of your knowledge, what was the lowest annual rate of inflation that your country experienced during the last 30 years?

   Correct answer Argentina: -1.17 %

   Correct answer UK: 0.05 %

3) To the best of your knowledge, what was the rate of inflation that your country experienced over the past year?

   Correct answer Argentina: 40.3%

   Correct answer UK: 1.6%

As the correct answers for these questions differed by country and their ranges were substantially different, a direct comparison of scores was not meaningful. Therefore, we calculated the distance between the correct answer and each participant's response and the absolute value of the whole measure per country. We ranked scores within each country and centred the mean of each country distribution to zero to counterbalance the effect of sample differences. The correct answers to these questions were obtained from the World Bank World Development indicators (2017) and from Inflation.eu (2017).

The measure *'Level of knowledge of calculation of impact of compound interest* is composed of four questions:

1) If inflation is **10%** a year, and a product currently costs US$1,000, how much will it cost in **one year's time**?

Correct answer: US$ 1100

2) If inflation is **50%** a year, and a product currently costs US$1,000, how much will it cost in **two year's time**?

Correct answer: US$ 2250

3) If inflation is **3%** a year, and a product currently costs US$1,000, how much will it cost in **five year's time**?

Correct answer: US$ 1159

4) If inflation is **100%** a year, and a product currently costs US$1,000, how much will it cost in **five year's time**?

Correct answer: US$32,000

For each question, the correct answer was assigned a value of 1, and 0 otherwise. The final measure is the sum of all for questions (range 0-4).

S2. Additional regressions

Table A2.1: OLS results applying exclusion criteria.

	Dependent variable: Area Under the Curve	
	(1)	(2)
Country of residence – UK *(Ref.: Argentina)*	0.133*** (0.035)	0.128*** (0.035)
Inflation rate condition - 2% *(Ref.: 20%)*	0.085** (0.032)	0.085** (0.032)
Gender - Male	0.042 (0.025)	0.007 (0.026)
Age	0.002 (0.001)	0.002 (0.001)
Level of education	0.007 (0.010)	-0.002 (0.010)
Income ladder	0.005 (0.008)	0.002 (0.008)
Country of residence - UK*Inflation rate condition - 2%	-0.051 (0.048)	-0.056 (0.047)
Knowledge of compound interest	-	0.026* (0.010)
Knowledge of previous inflation rates	-	-0.002** (0.001)
Constant	0.389*** (0.069)	0.394*** (0.070)
Observations	370	370
R^2	0.081	0.128
Adjusted R^2	0.064	0.106
Residual Std. Error	0.226 (df = 362)	0.221 (df = 360)
F Statistic	4.575*** (df = 7; 362)	5.858*** (df = 9; 360)

Note: *p<0.05; **p<0.01; ***p<0.001

S3. Shape of the discounting function – additional comments

Exponential discounting is represented by the following equation:

$$V = Ae^{-kD} \quad \text{(Eq. 1)}$$

where V is the subjective value of the delayed reward, A is the absolute value of the delayed reward, and D is the delay until receipt of the delayed reward. Exponential discounting is constant, leads to time-consistent decision making, and accounts for compounding of interest and the eroding effects of inflation over time.

Hyperbolic discounting is represented by the following equation:

$$V = A/(1+kD) \quad \text{(Eq. 2)}$$

where V is the subjective value of the delayed reward, A is the absolute value of the delayed reward, and D is the delay until receipt of the delayed reward. The parameter k represents the discount factor: a higher k indicates steeper discounting when the data are fitted to this function. In hyperbolic models of discounting, the discount rate is much higher for the immediate future than for the distant future. Thus, the value of a reward initially declines sharply with delay; however, an additional delay has relatively little effect on value, which can lead to preference reversals as the time of the smaller-sooner reward approaches (Green, Fry & Myerson, 1994; Kirby & Herrnstein, 1995; Loewenstein, 1988; Myerson & Green, 1995).

In order to determine which delay discounting model (exponential vs. hyperbolic) was a better fit to our data overall, we calculated fit statistics to the group median data for the discounting functions (Eqs. 1 and 2) as well as fits to individual data. The quality of a discounting model is not only determined by its ability to describe the aggregate behaviour of a group but also by its accuracy to describe the behaviour of the individuals in that group (see Green & Myerson, 2004). Table S3.1 shows the R^2 values for the discounting functions fitted to the group median data by country and inflation rate condition.

Table S3.1: Model fitting results

	20% condition		2% condition	
	Argentina	**UK**	**Argentina**	**UK**
Exponential R^2	.998	.998	.953	.945
Hyperbolic R^2	.997	.998	.992	.987

At the aggregate level, the hyperbolic model (Eq. 2) accounted for a higher proportion of the variance than the exponential model (Eq. 1) in both countries in the low inflation rate condition. In the high inflation rate condition, the R^2 values were very similar in both countries for both models. However, at the individual level, the R^2 for the hyperbolic model (Eq. 2) was higher than that of the exponential model (Eq. 1) in 278 (73 %) of the 381 participants who exhibited some kind of discounting[1], and the difference between these models was significant according to a Wilcoxon signed-rank test ($p < .001$).

S4. Interactions between treatment effects and participant characteristics

To test whether differences between samples and countries (participant characteristics) influence the results we repeated the main analysis including interactions between the treatment effects (country of residence and inflation rate condition) and socio-demographic characteristics.

[1] Of the total sample of 393 participants, 8 exhibited no discounting, 1 total discounting and 3 constant discounting across the four delays.

Table S4.1: Main analysis with interactions between country of residence and participant characteristics.

	Dependent variable: Area Under the Curve			
	(1)	(2)	(3)	(4)
Country of residence – UK *(Ref.: Argentina)*	0.121** (0.039)	-0.059 (0.089)	0.124 (0.072)	0.101 (0.097)
Inflation rate condition - 2% *(Ref.: 20%)*	0.065* (0.032)	0.063* (0.032)	0.064* (0.032)	0.065* (0.032)
Gender - Male	0.062 (0.033)	0.053* (0.025)	0.047 (0.025)	0.048 (0.025)
Age	0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
Level of education	0.002 (0.010)	0.005 (0.010)	0.005 (0.014)	0.003 (0.010)
Income ladder	0.002 (0.009)	0.0002 (0.009)	0.002 (0.009)	0.001 (0.012)
Country of residence - UK*Inflation rate condition - 2%	-0.033 (0.048)	-0.031 (0.048)	-0.035 (0.048)	-0.035 (0.048)
Country of residence - UK*Gender -Male	-0.033 (0.050)			
Country of residence - UK*Age		0.004* (0.002)		
Country of residence - UK* Level of education			-0.004 (0.019)	
Country of residence - UK*Income ladder				0.002 (0.017)
Constant	0.456*** (0.070)	0.545*** (0.081)	0.452*** (0.076)	0.465*** (0.087)
Observations	393	393	393	393
R^2	0.059	0.069	0.058	0.058
Adjusted R^2	0.040	0.049	0.039	0.039
Residual Std. Error (df = 384)	0.235	0.234	0.235	0.235
F Statistic (df = 8; 384)	3.028**	3.536***	2.977**	2.971**

Note: *p<0.05; **p<0.01; ***p<0.001.

Table S4.2: Main analysis with interactions between inflation rate condition and participant characteristics.

	Dependent variable: Area Under the Curve			
	(1)	(2)	(3)	(4)
Country of residence – UK *(Ref.: Argentina)*	0.107** (0.036)	0.102** (0.035)	0.110** (0.036)	0.108** (0.036)
Inflation rate condition - 2% *(Ref.: 20%)*	0.045 (0.037)	-0.131 (0.090)	0.075 (0.071)	-0.003 (0.098)
Gender-Male	0.020 (0.037)	0.042 (0.025)	0.048 (0.025)	0.047 (0.025)
Age	0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
Level of education	0.003 (0.010)	0.004 (0.010)	0.004 (0.013)	0.003 (0.010)
Income ladder	0.002 (0.009)	0.001 (0.008)	0.002 (0.009)	-0.005 (0.012)
Country of residence - UK*Inflation rate condition - 2%	-0.033 (0.048)	-0.019 (0.048)	-0.035 (0.048)	-0.030 (0.049)
Inflation rate condition - 2%*Gender - Male	0.051 (0.050)			
Inflation rate condition - 2%*Age		0.004* (0.002)		
Inflation rate condition - 2%* Level of education			-0.003 (0.019)	
Inflation rate condition - 2%*Income ladder				0.012 (0.017)
Constant	0.476*** (0.071)	0.574*** (0.085)	0.455*** (0.075)	0.498*** (0.087)
Observations	393	393	393	393
R^2	0.061	0.071	0.058	0.060
Adjusted R^2	0.041	0.052	0.039	0.040
Residual Std. Error (df = 384)	0.235	0.233	0.235	0.235
F Statistic (df = 8; 384)	3.110**	3.688***	2.973**	3.042**

Note: *p<0.05; **p<0.01; ***p<0.001.

S5. Participants' experience with inflation and treatment effects

Table S5: Main analysis with interactions between inflation rate condition and participants' experience with inflation (based on their age during periods of high inflation in each country).

	Dependent variable: Area Under the Curve	
	UK	Argentina
Inflation rate condition - 2% *(Ref.: 20%)*	0.016 (0.037)	0.017 (0.052)
Gender-Male	0.025 (0.036)	0.081* (0.035)
Experience with high inflation - UK	0.020 (0.068)	
Experience with high inflation - Argentina		-0.083 (0.052)
Level of education	0.001 (0.013)	0.007 (0.015)
Income ladder	0.001 (0.011)	-0.002 (0.013)
Inflation rate condition - 2%* Experience with high inflation - UK	0.115 (0.098)	
Inflation rate condition - 2%* Experience with high inflation - Argentina		0.076 (0.068)
Constant	0.632*** (0.069)	0.560*** (0.088)
Observations	174	219
R^2	0.033	0.049
Adjusted R^2	-0.002	0.022
Residual Std. Error	0.223 (df = 167)	0.243 (df = 212)
F Statistic	0.957 (df = 6; 167)	1.811 (df = 6; 212)

Note: *p<0.05; **p<0.01; ***p<0.001.