PSYCHOLOGICAL AND BIOLOGICAL FOUNDATIONS OF TIME PREFERENCE

Michael Daly
Trinity College Dublin

Liam Delaney
University College Dublin

Colm P. Harmon
University College Dublin

Abstract
This paper considers the relationship between the economic concept of time preference and relevant concepts from psychology and biology. Using novel data from a time diary study conducted in Ireland that combined detailed psychometric testing with medical testing and real-time bio-tracking, we examine the extent to which individual differences in financial discounting are related to underlying biological and psychological differences. The paper finds that financial discounting is related to a range of psychological variables including consideration of future consequences, self-control, conscientiousness, extraversion, and experiential avoidance, as well as being predicted by heart rate variability and blood pressure. (JEL: D01, D9, C81)

1. Introduction

The concept of time preference is central to economic theories of human behaviour. For example, models in health economics such as the Grossman model (Grossman 1972) and the Theory of Rational Addiction (Becker and Murphy 1988) rely heavily on concepts of time preferences and a growing body of research has been conducted to examine the realism of the assumptions of these models (Reynolds 2006). Particularly, recent papers have examined the biological and psychological foundations of time preferences in humans (Borghans et al. 2008; Frederick, Loewenstein, and O'Donoghue 2002).

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E-mail addresses: Daly: dalym7@tcd.ie; Delaney: Liam.Delaney@ucd.ie; Harmon: Colm.Harmon@ucd.ie

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The extent to which economic measures of time preferences are related to psychological concepts is still poorly understood. In particular, little is known to date about the relationship between time preferences and several plausibly related psychometric constructs such as future orientation, self-control, executive functioning, self-awareness, conscientiousness, and emotion regulation. Furthermore, although a body of work has emerged on the potential neural systems underlying time preferences (McClure et al. 2004; McClure et al. 2007), these papers have generally focused the interpretation of specific brain pathways obtained via neural imaging techniques. Very little work has examined other biological mechanisms relating, for example, to autonomic nervous system activation which, a priori, seem also likely to be implicated in decision making over different time horizons.

In this paper we address these deficits directly using an innovative primary data source which incorporates standard socio-demographics measures, discounting questions, and psychometric and biological measures. Specifically, we examine the extent to which time discounting is predicted by a broad range of psychometric and biological measures. The paper is structured as follows. Section 2 examines a number of plausible psychological and biological mechanisms that potentially relate to human discounting. Section 3 describes the data and study procedures. Section 4 examines the results of a number of different tests of association between economic measures of time preferences and biological/psychological measures. Section 5 concludes.

2. Literature

Research on individual differences in discounting has focused on cognitive factors such as IQ and numeracy, executive functions such as working memory, and non-cognitive traits such as impulsivity and sensitivity to reward (Reynolds 2006). Recent contributions have started to examine a broader range of potential non-cognitive psychological analogues to time preferences. Borghans et al. (2008) argue that time preferences are linked to the psychological concepts of conscientiousness and the ability to imagine future states. Conscientiousness is one component of the so-called "Big Five" personality taxonomy. Although other components of the "Big Five" could potentially be involved in future orientation (e.g., openness to experience may condition the set of alternatives conceived as future options), conscientiousness is particularly implicated in the ability to make sacrifices now for rewards later.

A trait which is closely related to the conscientiousness subcomponent of self-discipline is self-control. Self-control is an expansive concept that involves monitoring of self and regulation of behaviour in line with goals and self-imposed standards. In much of the recent literature, self-control has been conceived of as drawing from a limited resource (a willpower reserve) that can be attenuated by

tasks requiring effortful control of attention (Gailliot et al. 2007). The ability to utilise regulatory resources to actively regulate emotion and behaviour continuously through time in order to forego potential immediate rewards is likely to be strongly related to time preferences.

Resisting short-term reward in favour of longer-term alternatives also requires a capacity to envision the distant outcomes of current choices. The main psychometric measure of future orientation examines the extent to which individuals tend to make sacrifices for later reward or act out of convenience as opposed to in line with long-term goals (Strathman et al. 1994). A related construct in decision-making research is the capacity to generate and evaluate future counterfactuals which has been shown to relate to a tendency to consider future consequences (Nenkov, Inman, and Hulland 2008).

Alongside the ability to think about future outcomes, when confronted with decisions involving potential rewards over different time horizons, effectively altering the trajectory of the emotional response to temporally more immediate "hot" emotional stimuli is an essential part of time discounting. The role of emotion regulation in economic decisions has been discussed in a number of papers (Loewenstein and O'Donoghue 2007). For example, it has been shown that emotion regulation influences the pattern of trading among financial investors (Seo and Barrett 2007). Purposeful regulation of emotion involves reformulating the meaning of immediate affective stimuli and is associated with positive outcomes in terms of mood and life-satisfaction. Conversely, under-engagement with emotion and a tendency to inhibit emotion expressive behaviours and emotion related thoughts has been implicated in erratic and impulsive behaviour and may be involved in time discounting. Mood states may also have an independent influence on decision-making. In particular, experimentally induced negative emotional states have been shown to induce more impulsive responding. Positive affect has been shown to reinforce self-control and may support future directed behaviour.

Health bio-markers have also been discussed in relation to discounting. For example, it has been shown that overweight and obese people tend to discount the future more than those of normal weight (e.g. Borghans and Golsteyn 2006). Also, several economic models argue that individuals with higher discount rates will be more likely to invest poorly in health and thus have worse health than those with low discount rates. In terms of more fully understanding the biological processes involved in time discounting, several recent studies have examined the neural substrates involved in decision-making through time. McClure et al. (2004) demonstrate differential limbic system activation in the presence of immediate monetary rewards. They replicate these results in the presence of primary rewards (McClure et al. 2007) and argue that discounting can be thought of in terms of dual interacting systems, with the emotion focused subcortical limbic system recruited for decisions involving immediate tradeoffs and the more cognitively orientated frontal-parietal system involved in discounting across all tradeoffs.

However, less research has been conducted examining other biological research paradigms and the potential light that such paradigms might shed on economic discounting. Glucose has been widely discussed in the psychological literature as an essential biological "fuel" for self-control and decision making through time, involved particularly in the regulation of impulsive decisions and goal-directed behaviour (Gailliot et al. 2007). Thus, there is strong reason to believe that variation in glucose levels may provide information on the biological substrates implicated in economic discounting.

The extent to which autonomic sub-systems influence economic discounting has received little attention in the economics literature. Although the relationship between self-control and heart rate variability has been examined in a number of papers (Segerstrom and Solberg 2007), no paper to date has examined the potential role of heart rate variability in economic discounting. Given that many of the brain regions responsible for autonomic regulation have also been implicated in time discounting, this provides strong reason to believe that blood pressure, heart rate and heart rate variability may be important markers for similar processes to economic discounting. High and invariable heart rates have also been demonstrated to correlate with impulsivity (Krueger, Schedlowski, and Meyer 2005). As high heart rate variability and low heart rate and blood pressure are indicative of consistent strong of physiological processes there is substantial evidence that autonomic measures are therefore likely to be associated with the ability to defer reward. Thus, integrating assessments of autonomic function into both laboratory and field-based discounting studies offers the potential to open up a new and fruitful measurement paradigm.

3. Study and Measures Used

The data used in this paper are drawn from an on-campus study of students from Trinity College Dublin (TCD). Students were recruited on campus based on the response to a college wide e-mail request for participation the study. A combination of monetary and course-credit incentives were offered in return for participation. Two hundred four (204) students agreed to full participation. Sixty-four percent (64%) of the sample were female and the mean age of the participants was 24.5 years (SD = 6.5).

Each participant was given an initial medical test involving blood pressure, body fat impedance analysis, blood glucose, weight, and height. This was completed on behalf of the study by the research nurse team at the Clinical Research Centre at the Mater Misericordiae Hospital in Dublin, a teaching hospital of University College Dublin. Respondents were then given instructions on the use of the portable heart monitoring devices. They wore these from waking on the following day until bedtime. Finally, on the third day respondents completed a Web-based

questionnaire including the day reconstruction method (Kahneman et al. 2004) and a large battery of psychometric and demographic tests. Table 1 outlines the measures and data instruments utilised throughout the programme of work.

In a follow-up study, respondents were asked to participate in an economic discounting study and 150 of the original 204 agreed. In this paper we estimate a simple specification of the form $D_i = F(X_i, f(P_i, B_i))$ where, for i individuals, D represents a measure of discounting behaviour, X represents a set of socio-demographic variable, P represents a set of psychometric measures, and B is a set of biological measures.

The measure of discounting behaviour used in the paper is a monetary task model following Kirby, Petry, and Bickel (1999), where respondents were offered a fixed set of 27 binary choices between smaller, immediate rewards that the person can have today and larger, delayed rewards that the person can have at some date in the future. The participants were instructed to take the choices seriously, that choices may be for real money and that the money will be delivered to them at the appropriate time if they were to win. Each participant's choices were converted into a discount-rate parameter which is calculated as the geometric mean k value derived from indifference points approximations for small, medium, and large rewards offered to respondents for each choice. Larger assigned discounted values indicate a greater tendency to discount the value of future rewards with the relationship between immediate and delayed rewards identified by the estimated k value as follows: $k = (A - V)/V \times D$, where $A =$ the delayed value, $V =$ the immediate value, and $D =$ the magnitude of the delay (see Kirby et al. for the table of payoffs used and details regarding the computation of individual discount rates). A second binary measure assessed choice consistency defined as selecting a delayed option associated with a lower k value than another choice where the participant selected an immediate option. Table 1 outlines the measures and data instruments utilised (the P and B variables) throughout the estimations.

4. Results

4.1. Descriptive Statistics

Table 2 displays descriptive statistics on key variables used in the study. It also displays the raw correlation of each variable with the discount scores calculated based on responses in the financial discounting task. Lower discounting in the financial discounting task is associated with high scores on conscientiousness, self-control, consideration of future consequences, cognitive/affective mindfulness, and low scores on experiential avoidance and extraversion. For example the mean k-value for all 150 respondents is 0.009 whereas it is 0.013 for respondents in the bottom quartile of the CFC distribution and 0.007 for respondents in the top

TABLE 1. Measures used in the study.

	Explanation
Monetary Choice Task	Respondents are offered a series of 27 choices involving monetary rewards at different time intervals. Measures the extent to which individuals discount the value of future financial outcomes.
Ten-Item Personality Inventory	Short-form Big Five Inventory assessing the broad dimensions of personality: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness (Gosling, Rentfrow, and Swann 2003).
Self-Control Scale	A 13-item measure which captures individual differences in the ability to exercise self-control in controlling impulses, emotions, thoughts, and performance (Tangney, Baumeister, and Boone 2004).
Consideration of Future Consequences Scale	The CFC is a 12-item subjective elicitation measure focused on future orientations (Strathman et al. 1994).
Elaboration of Potential Outcomes	Measures the extent to which individuals generate positive and negative consequences of their behaviours and the degree to which they evaluate the importance of such consequences (Nenkov et al. 2008).
Emotional Regulation Questionnaire	Captures two common emotional regulation strategies: (1) cognitive reappraisal or changing how one thinks about an emotion-eliciting event, and (2) expressive suppression or reducing the behavioural expression of emotion when one is in an emotional state (John and Gross 2004).
Cognitive and Affective Mindfulness	A 12-item scale assessing the attention, awareness, present-focus, and acceptance facets of the mindfulness construct (Feldman et al. 2007).
White Bear Suppression Inventory	Self-report measure assessing the general tendency to suppress unwanted thoughts which is associated with obsessive thinking and emotional reactivity (Wegner and Zanakos 1994).
Acceptance and Action Questionnaire	Measures experiential avoidance: The tendency to negatively evaluate and avoid contact with particular private experiences (Hayes et al. 2004).
Day Reconstruction Method	The DRM is a measure of evaluated time-use which assesses the experience of daily affect through eliciting ratings of episodes experienced by respondents (Kahneman et al. 2004).
Health Bio-markers	Body fat (estimated percentage of total mass) and Body Mass Index (BMI) were assessed.
Autonomic Nervous System Monitoring	Heart rate was continuously tracked from waking to sleeping. Resting blood pressure was also assessed.
Glucose Monitoring	Blood glucose was measured using a pin-prick test at the beginning of the study.

TABLE 2. Descriptive statistics on psychometric variables and raw correlation with discount parameter.

Variable	Obs	Mean	Std. Dev.	k value
Conscientiousness	149	9.46	2.79	−0.15*
Extraversion	149	9.43	2.79	0.16**
Nervousness	149	7.07	3.02	0.11
Openness	149	10.95	2.23	0.01
Agreeableness	149	9.76	2.15	−0.11
Self-Control Scale	149	39.49	8.32	−0.14**
Consideration of Future Consequences	149	43.30	7.15	−0.18**
Elaboration	149	29.01	6.30	−0.11
Positive Elaboration	149	13.99	4.06	−0.02
Negative Elaboration	149	15.54	6.02	0.07
Cognitive Reappraisal	149	26.73	6.14	0.10
Expressive Suppression	149	12.58	4.93	−0.03
Cognitive Affective Mindfulness Scale	149	31.06	5.28	−0.13*
Thought Suppression	149	40.97	12.90	0.07
Experiential Avoidance	149	34.24	6.41	0.26***
Positive Affect	147	21.17	4.57	−0.07
Negative Affect	147	5.44	3.09	0.02

Note: *Significant at $p < 0.1$; **significant at $p < 0.05$; ***significant at $p < 0.01$.

quartile of the CFC distribution. This means that for those in the bottom quartile $50 would lose half of its value in 77 days, whereas for those in the top quartile $50 would take 143 days to halve in value.

Table 3 displays descriptive statistics on a number of biological markers: mean heart rate, standard deviation of heart rate, systolic and diastolic blood pressure, as well as the correlation of these variables with the discount rate displayed in the financial task. As can be seen, discount rates correlate negatively with heart rate variability and positively with systolic blood pressure. For example, respondents with systolic blood pressure in the top quartile have a k-value of 0.013 and respondents with systolic blood pressure in the bottom quartile have a k-value of 0.001.

TABLE 3. Descriptive statistics on biological variables and correlation with discount parameter.

Variable (units)	Obs	Mean	Std. Dev.	k value
Body Fat (%)	149	28.66	8.37	−0.12
BMI (kg/m^2)	149	23.18	3.88	0.12
R-R (interbeat interval)	139	723.94	108.77	−0.06
HRV (SD of R-R)	139	141.65	45.86	−0.15*
Sys BP (mmHg)	149	123.43	12.94	0.29***
Dia BP (mmHg)	149	69.48	9.72	0.13
Glucose (mmol/L)	148	5.22	0.69	−0.11

Note: *Significant at $p < 0.1$; **significant at $p < 0.05$; ***significant at $p < 0.01$.

4.2. Factor Analysis of Measures

The extent to which this large array of proxies for time preferences can be reduced to a smaller number of underlying dimensions can be examined through factor analysis. The rotated factor matrix from a factor analysis is displayed in Table 4. Four factors with eigenvalues greater than one emerged from the analysis. The first factor is associated in particular with high values on positive affect and positive elaboration and low values on neuroticism, negative elaboration, and experiential avoidance. It is reasonable to think of this factor as representing a dispositional trait toward higher well-being. The second factor is associated, in particular, with self-control, consideration of future consequences, elaboration of consequences, cognitive/affective mindfulness, and conscientiousness. It thus loads well on several well-known constructs conceptually related to economic discounting. The third factor is clearly heart rate level and variability and the fourth factor is blood pressure.

4.3. Predictors of Financial Discounting

We use the four constructed variables, along with age and sex as covariates in models of patience in the discounting task. The results are displayed in Table 5.

TABLE 4. Rotated factor matrix.

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Conscientiousness	−0.13	0.73	−0.13	0.03
Extraversion	−0.40	−0.23	0.15	−0.18
Nervousness	0.70	−0.08	0.21	0.12
Openness	−0.03	−0.23	0.23	0.02
Agreeableness	−0.20	0.21	0.18	0.08
Self-Control Scale	−0.18	0.78	−0.15	−0.01
Consideration of Future Consequences	0.06	0.58	0.07	−0.03
Elaboration	0.07	0.60	0.19	−0.08
Positive Elaboration	−0.69	−0.03	0.15	−0.07
Negative Elaboration	0.72	−0.02	0.09	−0.08
Cognitive Reappraisal	−0.22	0.21	0.28	−0.16
Expressive Suppression	0.29	0.03	−0.20	0.00
Cognitive Affective Mindfulness Scale	−0.57	0.51	−0.01	0.09
Thought Suppression	0.57	−0.23	0.00	−0.13
Experiential Avoidance	0.68	−0.34	−0.03	−0.06
Positive Affect	−0.43	0.00	0.24	−0.25
Negative Affect	0.56	0.10	0.11	0.17
Body Fat	0.00	0.11	0.32	0.12
BMI	−0.08	−0.09	−0.01	0.52
Heart Rate	−0.03	0.09	−0.76	0.04
Heart Rate Variability	−0.12	0.14	−0.62	−0.08
Systolic Blood Pressure	0.02	−0.05	−0.08	0.76
Diastolic Blood Pressure	0.06	0.16	0.28	0.58
Blood Glucose	0.01	−0.03	−0.04	0.30

TABLE 5. Predictors of financial discounting.

	Age	Sex	F1	F2	F3	F4	Constant
Discount Rate	0.000	−0.002	−0.001	−0.003***	−0.001	0.002*	0.011**
	(0.000)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)
Inconsistency	−0.047*	−0.036	0.029	−0.001	−0.020	0.308*	0.468
	(0.026)	(0.308)	(0.137)	(0.138)	(0.155)	(0.166)	(0.747)

Note: *Significant at $p < 0.1$; **significant at $p < 0.05$; ***significant at $p < 0.01$.
Standard errors in parentheses.

As can be seen, neither age nor sex exerts a significant influence on the patterns involved. However, age is associated with a significantly lower probability of choice inconsistency. Factor 2 is significantly associated with greater patience in the financial discounting task and this is robust to several different methods of scoring the discounting task and of specifying the error distributions. Factor 1 is significant and positive in some models though this depends on the handling of outliers and the error specifications. Similarly, Factor 4 (representing blood pressure) predicts discounting in the expected direction and is significant in several models. The coefficients represent the effect of a one-standard-deviation unit change in the factor on the discount rate. Thus, for example, an increase of one standard deviation in the second factor predicts approximately a decrease of 0.003 in the discount rate from a mean value of 0.009.

5. Discussion

In this paper we examined the relationship between economic discounting and a range of psychological and biological variables. Our results suggest that financial discounting is associated with a number of variables measuring future orientation. The results of a factor analysis incorporating measures of self-control, cognitive appraisal, emotional regulation, personality, heart rate functioning, blood pressure, and blood glucose yielded four main factors: affect; self-control; heart rate; and blood pressure. In particular, there is strong evidence that self-control has a strong independent effect on measures of patience in financial discounting tasks. Furthermore, there is some evidence to support the claim that affect has a role in discounting and that heart rate variability and blood pressure are associated with discounting. This is the first time that such an analysis has been conducted in the context of economic discounting and it lends substantial evidence to a number of theoretical accounts of decision-making that examine the linkages between psychological, biological, and economic models of discounting.

This work is clearly not without limitations. As stressed by Borghans et al. (2008) and in the dynamic models of human capital formation of Heckman (2007), the potential interplay between measures is missing from this analysis.

The extent to which concepts such as self-control, future orientation, conscientiousness and others can be arranged into hierarchical systems is a key task for future research. The future of this research will utilise larger samples to overcome power limitations and incorporate panel data in order to examine dynamic changes in the variables and their effect on discounting over time. In terms of expanding the current scope of variables assessed, conceptually related constructs such as sensation seeking, numeracy, and sustained attention will be incorporated in subsequent rounds of the study and discounting will be examined across a wider set of domains and time horizons. Where feasible, the examination of the effect of within-person manipulation of psychological and biological variables on delay discounting will be evaluated through experiments. This will allow more robust inferences to be made regarding the causal role of these variables in determining time preferences.

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