Physical Activity, Present Bias, and Habit Formation: Theory and Evidence From Longitudinal Data

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Abstract

We investigate temporal decisions to participate in exercise in a dynamic model featuring present bias and habit formation. The model highlights naivete about present bias and projection bias about habit formation/decay and implies that promoting participation in physical activity must both encourage the inactive to start and discourage the active from quitting as behavioral biases apply to both. Our empirical analysis using data from the British Household Panel Survey (BHPS) develops evidence consistent with predictions about present bias and habit formation/decay and an interesting asymmetry between starting and quitting that furthers understanding of existing empirical evidence.

JEL Codes: D1, I12, L83

Key Words: present-bias, physical activity, habit formation, habit decay, projection bias

1   Introduction

Promoting regular physical activity and reducing disparities in physical activity represents an important public policy priority because of the many health benefits associated with regular physical activity. Physically active people are less likely to be obese and less likely to suffer from chronic health conditions like diabetes, high blood pressure, heart disease and cancer. Further, preventing obesity in part through regular physical activity is important because once obese, the probability of returning to a healthy weight is low (Fildes et al., 2015). Despite all we know about the health benefits of physical activity, and numerous campaigns to promote it, many people still do not engage in the recommended levels of physical activity to achieve sustainable health benefits. Participation in physical activity, like many other health behaviors, is episodic. Some people exercise regularly, while others do not. Some people begin to exercise regularly but then stop and start again. An improved understanding of patterns in physical activity behavior over time may help to design and implement more effective policies aimed at promoting physical activity.

This paper is inspired by the literature on consumers' choice of health club contracts and attendance decisions. DellaVigna and Malmendier (2006), and Garon et al. (2013) find evidence of over-confidence in future health club attendance consistent with consumers' naivete about their own present bias. Charness and Gneezy (2009) and Acland and Levy (2015) find evidence of post-intervention effects of paying subjects to exercise at health clubs consistent with habit formation. In addition, Acland and Levy (2015) find evidence of naivete with respect to present bias and projection bias with respect to habit formation. These studies significantly advanced our understanding of behavioral patterns in gym and health club attendance.

Whether and how these findings can be generalized to the broader area of individual participation in physical activity are important questions for extending this literature. We assess this in two ways. First, whether decisions about gym or health club attendance can be generalized to other forms of leisure time participation in physical activity, such as walking for exercise, going for a jog or run, or exercising in the home. Second, whether the behavioral patterns observed in the special subject groups used in these studies can be extended to a more general population.[1] The objective of this research is to develop and empirically test a dynamic model of participation in physical activity that features the behavioral patterns identified by the gym attendance literature, and to test the predictions of this model using data from a nationally representative survey.

Our theoretical model builds on dynamic inconsistency models developed by O'Donoghue and Rabin (1999b) and includes habit formation (Becker and Murphy (1988)) and projection bias (Loewenstein et al. (2003)). Our model abstracts from the contracting aspects associated with health club membership and attendance emphasized in the models developed by DellaVigna and Malmendier (2006) and Acland and

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[1]The subjects in Acland and Levy (2015)'s study are students and staff of the University of California, Berkeley. Charness and Gneezy (2009) study students from the University of Chicago and University of California, San Diego. DellaVigna and Malmendier (2006) study members of three health clubs in New England and Garon et al. (2013) study members at 14 health clubs in Quebec.

Levy (2013) to focus on decisions about participating in general leisure time physical activity. Physical activity is modeled as a task with immediate costs, in terms of money, time, effort, and psychic costs[2] and delayed rewards, in terms of benefits associated with improved health and weight loss. The habit of participation in physical activity is a binary state variable (O'Donoghue and Rabin (1999a) and Acland and Levy (2013)): people who enter a period with the habit of participation in physical activity will face a lower effort cost of participation in the current period than people who enter without the habit. The habit of participation is defined by participation in the period immediately before the current period, which means that the model implicitly includes habit decay. The model also includes conventional economic motivations such as monetary and time costs associated with participation emphasized by Humphreys and Ruseski (2011) and a stochastic period-specific participation cost shock.

The theoretical model yields a rich set of predictions on temporal decisions about participation in physical activity. Predictions regarding naivete and projection bias are not directly testable with secondary data that have no information on individuals' ex ante "prediction/perception" of own behavior. The British Household Panel Survey (BHPS), the data we use for our empirical analysis, unfortunately does not contain such information. However, the BHPS are rich enough to test other predictions, including the role of present bias and habit formation (and decay) in physical activity participation. The BHPS is a nationally representative longitudinal sample of households residing in England, Scotland, Wales and Northern Ireland. This survey began in 1991 and has been surveying participants annually since. BHPS participants are contacted annually and asked a comprehensive set of questions on topics ranging from employment status and wages and income to health status and education. We document participation in physical activity using data from waves 10 (2000), 12 (2002), 14 (2004) and 16 (2006) of the BHPS which included questions about the frequency of participation in physical activity.

When direct measures of individuals' time preference are not available, the critical aspect of empirically testing the negative impact of present bias on physical activity participation lies in finding a reasonable proxy for present bias. Studies that link directly elicited time preference measures to individual outcomes have found significant correlation between present bias and smoking (Burks et al. (2012), Grignon (2009) and Kang and Ikeda (2013)) and accumulation of credit card debt (Meier and Sprenger (2010)). We use information from the BHPS to construct proxy variables for present bias using responses to questions about past smoking and accumulation of credit card debt. We find that the probability of starting and continue to participate in physical activity in later periods (2002, 2004, and 2006) was negatively correlated with smoking in 2000 and the accumulation of credit card debt by 2000. The probability of quitting participating in physical activity was positively correlated with smoking in 2000 but not with the accumulation of credit card debt by 2000. Overall, these results, when combined with findings from the time preference literature, support the idea that present bias negatively affects participation in physical activity in the general population.

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[2]The model allows negative effort and psychic costs. For people with negative effort costs, they actually enjoy physical activity and participate not just for the health benefits but also for the enjoyment.

The difficulty in empirically testing the role of habituation in decisions to participate in physical activity using secondary data is endogeneity. An observed correlation between past participation and current participation can purely reflect unobserved personal traits or learning about physical activity through experience. We explore individuals' past participation history in different ways to test these two alternative hypotheses. First, we estimate the impact of participation in 2000, 2002, and 2004 on the probability of participation in 2006. If there is no effect of habit formation and decay and past participation is correlated with current participation through time-invariant unobservable personal traits, then the coefficient on the three past participation variables should be the same. We find that all three coefficients are positive and significantly different from each other: the coefficients of past participation decline with the time between the current period and the past participation period, favoring habit formation and decay. Second, we limit our sample to individuals who participated in physical activity in 2000 and 2002 who may have gone through the learning process before 2004. We find that, for this group with a relative long history of past participation, participation in 2004 significantly increases their probability of participation in 2006. This result is consistent with habit formation and decay and against learning unless learning is slow and takes more than 4 years.

Our empirical analysis also uncovers an interesting asymmetric impact of major events on quitting and starting participation in physical activity that analysis using cross-sectional data cannot reveal. We find that removing negative factors — a change in marital status, having children under 12, and reporting not enough leisure time that significantly reduce participation through increased probability of quitting — does not seem to increase the probability of starting participation. Consistent with habit formation and decay, this asymmetry implies that negative transitory shocks may lead to persistent non-participation in physical activity even though these shocks are not persistent.[3] This problem will be exacerbated if people have projection bias regarding habit formation and decay: people may quit too easily because they underestimate the effect of habit decay when they are participating, and they may be overly hesitant to start because they underestimate the effect of habit formation when they are inactive.

We also investigate the role of other socioeconomic and psychological variables that have been studied in the literature using secondary data. Cobb-Clark et al. (2014) analyze longitudinal survey data from Australia, the Household Labour, Income, and Dynamics in Australia (HILDA) Survey, and find that individuals with a strong internal locus of control tend to exercise regularly (report exercising at least three time per week) and engage in other healthy behaviors more than individuals with a weaker internal locus of control. Consistent with the findings in Cobb-Clark et al. (2014), we find that individuals with a weak internal locus of control are less likely to start participating in physical activity. We also find that having a university degree is correlated with a higher probability of starting and continuing participation, and a lower probability to quitting participation. Interestingly, income and hourly wage are generally not significant while the

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[3]With habit formation and decay, a positive participation shock of the same size as the negative participation shock just big enough to induce an individual to quit will not be big enough to induce the same individual to start again.

time constraint is significantly correlated with a higher probability of quitting and a lower probability of participating.

2 Patterns of participation in longitudinal data

Much of the recent existing evidence on the economic determinants of participation in physical activity comes from cross sectional data (Farrell and Shields, 2002; Downward, 2007; Humphreys and Ruseski, 2007; Eisenberg and Okeke, 2009; Humphreys and Ruseski, 2011; Brown and Roberts, 2011; García et al., 2011; Anokye et al., 2012; Humphreys et al., 2014; Kokolakakis et al., 2012). While cross sectional data typically contain large sample sizes and detailed information on the economic and demographic characteristics of participants and non-participants, analyzing participation outcomes at a point in time cannot reveal information about the decisions to quit, start, or continue to participate in physical activity over time. The World Health Organization recommendations on physical activity and health (World Health Organization, 2010) recommend sustained participation in physical activity over time, so a complete understanding of the economic determinants of participation in physical activity must look beyond cross sectional data and examine participation decisions made by individuals over time.

2.1 Data Description

We obtained data from the British Household Panel Survey (BHPS), an annual longitudinal survey of approximately 10,000 individuals over the age of 16 residing in England, Scotland, Wales and Northern Ireland that contains detailed questions on participation in physical activity. The BHPS sample is nationally representative of the UK population. Each year of data is referred to as a "wave." The original sample, wave 1, was identified and contacted in 1991 and contained about 5,500 households residing in England; additional samples from Scotland and Wales were added in wave 9 (1999) and a third sample from Northern Ireland was added in wave 11 (2001).

BHPS participants are contacted annually and asked a comprehensive set of questions on topics ranging from employment status and wages and income to health status and education. Not all questions are asked annually. We focus on participation in exercise and physical activity. Questions on participation in physical activity and exercise are included in the questionnaire every other year. We analyze data from waves 10, 12, 14 and 16 (2000, 2002, 2004 and 2006), which includes the original sample of households from England and the added samples from Scotland and Wales.

The question about participation in physical activity is included in a set of questions focusing on leisure time activities. The question reads: "We are interested in the things people do in their leisure time, I'm going to read out a list of some leisure activities. Please look at the card and tell me how frequently you do each one." One of the activities listed is "Play sport or go walking or swimming." Possible answers

include: At least once a week (1); At least once a month (2); Several times a year (3); Once a year or less (4); Never/almost never (5).

We use responses to this question to identify regular participants in exercise or physical activity. We assume that individuals who report that they "play sport or go walking or swimming" at least once a week are regular participants in physical activity. The WHO recommended levels of physical activity for health benefits for individuals aged 18 to 64 are 150 minutes of moderate-intensity physical activity per week.e strengthening activities. Individuals in the BHPS who participate in physical activity "at least once a week" may or may not meet this requirement, but this is the most detailed information available on participation in physical activity in the survey.

Table 1: Summary Statistics - Participation in Physical Activity 2000-2006

# of survey waves with reported active participation in PA	frequency	%
0	417	16.21
1	448	17.42
2	417	16.21
3	550	21.38
4	740	28.77

Type of reported participation spell	frequency	%
Never Participated	417	16.21
Started participating	427	16.60
Participated sporadically	597	23.21
Quit after regular participation	391	15.20
Always participated	740	28.77
Total	2572	100.00

The top panel on Table 1 shows the distribution of reported participation in regular physical activity in the sample. The question about participation in physical activity appeared in four waves (2000, 2002, 2004 and 2006). Regular continuous participation was the most commonly reported outcome, and participating in all but one wave was also a common outcome.

The bottom panel on Table 1 shows the distribution of temporal decisions about participation in the sample. Of the 2572 individuals between age 25 and 50 that appeared in the sample in Waves 10 through 16, about 16% reported never participating in regular physical activity over this period. 28% reported regular, continuous participation in physical activity in all four waves. The rest of the sample, about 53%, reported regular participation in 1, 2 or 3 of the survey waves. These individuals engaged in episodic participation in

physical activity. From the bottom panel of Table 1, about 17% were inactive at the beginning of the period but started regular participation at a later point, and about 15% were physically active at the beginning of the sample period and quit at some point.

These temporal patterns in participation paint a more complex picture of participation decisions than can be seen in cross-sectional data. A substantial number of people participate regularly over a sustained period of time, and another large group of people either quit or start regular participation over this period. Observed participants in physical activity in cross sectional data could be regular participants or could have recently started regular participation. Observed non-participants might never have participated or might have recently quit after a spell of regular participation. Since the WHO recommendations stress sustained participation, theoretical and empirical evidence that takes into account the temporal nature of participation in physical activity can shed new light on this decision that may help to design effective interventions to attract new participants and promote habituation to regular physical activity.

3 A model of physical activity participation decisions

We develop a behavioral economic model featuring formation, time inconsistent preferences, including naive and sophisticated individuals, and projection bias with respect to habit formation and decay to explain why individuals start, quit, and continue to participate in physical activity. The model also includes a participation-specific cost shock and emphasizes the traditional economic factors that affect the decision to participate in physical activity. The model developed here differs from DellaVigna and Malmendier (2006) and Acland and Levy (2013) in that it applies to general decisions about leisure time participation in physical activity, including activities like taking a walk, going for a jog or run, or performing exercises in the home. We do not address the decision to join a gym or fitness club, and the related contracting decision involving interaction between gym operators and potential members.[4]

3.1 Habit formation, Present bias, and Naivete

Consider a dynamic discrete-time, discrete choice model with periods $t = 1, \ldots, T$. In each period individuals either participate in physical activity ($a_t = 1$) or do not participate ($a_t = 0$). Individuals choose only current participation and cannot commit to any future actions.

We adopt the general habit formation framework proposed by Becker and Murphy (1988) where instantaneous utility in period t is $u_t(a_t, k_t)$ and k_t summarizes the history of the activity of interest. Like O'Donoghue and Rabin (1999a) and Acland and Levy (2013), we simplify k_t to be a binary state variable where $k_t = a_{t-1} = \{0, 1\}$.

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[4]DellaVigna and Malmendier (2006) develop a model of contract choice and health club attendance that includes stochastic effort costs and delayed health benefits. Acland and Levy (2013) develop a model of gym attendance that includes habit formation, projection bias, and present-biased preferences.

Assume that participation in physical activity involves immediate psychological, physical, time and financial costs. e_t reflects immediate psychological and physical effort costs, T_t time costs, and c_t the financial costs associated with participation in physical activity. We assume that habitual physical activity reduces psychological and physical effort costs, but not other costs, in that

$$
e_t = \begin{cases} e & \text{if } a_{t-1} = 0 \\ e - e_h & \text{if } a_{t-1} = 1 \end{cases}
$$

where $e > 0$ and $e_h > 0$. Note that $e - e_h$ can be positive or negative, so individuals habituated to physical activity may experience a net immediate utility gain.[5]

We assume that participation in physical activity in the current period improves health and utility in the following period, generating future benefits of $v \geqslant 0$. We model the instantaneous utility as additively separable in income and leisure time, taking the form

$$
u_t\left(a_t, a_{t-1}\right) = \begin{cases} f(y_t - c_t) + g(l_t - T) - e - \varepsilon_t & a_t = 1, a_{t-1} = 0 \\ v + f(y_t - c_t) + g(l_t - T) - (e - e_h) - \varepsilon_t & a_t = 1, a_{t-1} = 1 \\ f(y_t) + g(l_t) & a_t = 0, a_{t-1} = 0 \\ v + f(y_t) + g(l_t) & a_t = 0, a_{t-1} = 1 \end{cases}
$$

where y_t and l_t are income and total leisure time available. y_t and l_t are assumed to be exogenous to participation in physical activity. $f(\cdot)$ and $g(\cdot)$ are assumed to have the standard properties: $f'(\cdot), g'(\cdot) \geqslant 0$, and $f''(\cdot), g''(\cdot) \leq 0$. $\varepsilon_t > 0$ is a random cost shock that affects the immediate cost of participation in physical activity and is revealed to individuals at the beginning of period t. The period-specific cost shock reflects unexpected changes that affect participation, including changes in general health, injuries, good or bad weather conditions, unexpected time pressures related to work, commuting, or family responsibilities, the unexpected closing of a nearby gym, car problems, over-sleeping, and a myriad of other factors that might prevent someone from exercising at a given point in time. Note that ε_t is a participation-specific cost shock, not a general shock to instantaneous utility.

We assume that intertemporal preferences are potentially time-inconsistent with present bias as in the (β, δ)-model developed by Laibson (1997) and O'Donoghue and Rabin (1999b). Intertemporal preferences at time t, U^t, are represented by a utility function

$$
U^t(u_t, u_{t+1}, \ldots, u_T) \equiv \delta^t u_t + \beta \sum_{\tau=t+1}^{T} \delta^\tau u_\tau
$$

where $\beta \in (0, 1]$ and $\delta \in (0, 1]$. The parameter δ is the long-run, time-consistent discount factor and β captures potential present bias. If $\beta = 1$, intertemporal preferences are time consistent. If $\beta < 1$, then

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[5]If $e - e_h < 0$, then participating in physical activity is "fun". In this case, physical activity can be viewed as an entertainment that has delayed benefits.

intertemporal preferences are present biased as the relative weight given current period instantaneous utility is larger that the weight given future utility.

Present-biased preferences lead to self-control problems, and individual's awareness of this issue affects their decisions about participation in physical activity. Following the terminology of O'Donoghue and Rabin (1999b), we refer to individuals as "sophisticated" if they know exactly what their future β will be and anticipate that their future behavior will be influenced by β when making current period decisions.

We refer to individuals as "partially naive" if they believe their future present bias will be $\widetilde{\beta} \in (\beta, 1]$ when they make current period decisions about participation in physical activity.

Following the literature on time-inconsistent preferences, we assume that an individual consists of a series of autonomous selves, one for each period. Each period-t self chooses a_t to maximize the period-t continual (long-run) utility $U^t(u_t, u_{t+1}, ..., u_T)$ based on $(l_t, y_t, a_{t-1}, \varepsilon_t)$ and her beliefs about future decisions.

Following Fang and Wang (2010), let χ denote the support of information $(l_t, y_t, a_{t-1}, \varepsilon_t)$. We define a *strategy profile* for all selves to be $a \equiv \{a_t\}_{t=1}^T$ where $a_t : \chi \to \{0, 1\}$ for all t. The strategy profile specifies an individual's action in all possible states and under any possible realization of shocks. For any a, define $a^t \equiv \{a_\tau\}_{\tau=t}^T$ as the *continuation strategy profile* from period t on.

A partially naive individual's period-t self believes that, even though her current period present-bias is governed by β, beginning next period, her future selves will choose actions optimally with a present-bias parameter $\widetilde{\beta} \in (\beta, 1]$. We define such an individual's *perceived continuation strategy profile* to be $a(\widetilde{\beta}) \equiv \left\{ a(\widetilde{\beta})_t \right\}_{t=1}^T$ such that

$$a(\widetilde{\beta})_t(l_t, y_t, a_{t-1}, \varepsilon_t) = \arg \max_{a_t \in \{0,1\}} \left(u_t(a_t; l_t, y_t, a_{t-1}, \varepsilon_t) + \widetilde{\beta}\delta E[W_{t+1}(l_{t+1}, y_{t+1}, a(\widetilde{\beta})_t, \varepsilon_{t+1}; a(\widetilde{\beta})^{t+1})] \right).$$

$E[W_{t+1}(\cdot)]$ is expected continuation utility. Note that $a(\widetilde{\beta})$ is not the actual strategy profile that a partially naive person will follow; rather, an individual's period-t self believes that her future selves will follow $a(\widetilde{\beta})^{t+1} \equiv \left\{ a(\widetilde{\beta})_t \right\}_{\tau=t+1}^T$. The observed strategy profile is defined as $a^* \equiv \{a_t^*\}_{t=1}^T$ such that

$$a_t^*(l_t, y_t, a_{t-1}, \varepsilon_t) = \arg \max_{a_t \in \{0,1\}} \{u_t(a_t; l_t, y_t, a_{t-1}, \varepsilon_t) + \beta\delta E[W_{t+1}(l_{t+1}, y_{t+1}, a_t^*, \varepsilon_{t+1}; a_{t+1}^*)]\}.$$

When $\widetilde{\beta} = \beta$, an individual is sophisticated about present bias and the perceived continuation strategy profile and the observed strategy will be the same.

Consider an individual with $\widetilde{\beta} \in [\beta, 1]$. In period t, she believes that from period $t + 1$ on, her present bias parameter will be $\widetilde{\beta}$ and she makes current choices based on $\widetilde{\beta}$. Because her current period choice is affected by her perception of future choices, we first solve for her *perceived continuation strategy profile* $a(\widetilde{\beta})^{t+1} \equiv \left\{ a(\widetilde{\beta})_\tau \right\}_{\tau=t+1}^T$, and then solve for her actual decision path.

First, we simplify the notation in the instantaneous utility function

$$u_t(a_t, a_{t-1}) = \begin{cases} f(y_t - c_t) + g(l_t - T) - e - \varepsilon_t & = u_{10} - \varepsilon_t & a_t = 1, a_{t-1} = 0 \\ v + f(y_t - c_t) + g(l_t - T) - (e - e_h) - \varepsilon_t & = u_{11} - \varepsilon_t & a_t = 1, a_{t-1} = 1 \\ f(y_t) + g(l_t) & = u_{00} & a_t = 0, a_{t-1} = 0 \\ v + f(y_t) + g(l_t) & = u_{01} & a_t = 0, a_{t-1} = 1 \end{cases}$$

For ease of interpretation, $u_t(a_t, a_{t-1} = u_{10}$ represents the instantaneous utility function of a starter because $a_t = 1$ and $a_{t-1} = 0$. Similarly, u_{11} represents an individual who always participates; u_{00} represents an individual who never participates; and u_{01} represents a quitter because $a_t = 0$ and $a_{t-1} = 1$. Note that $u_{11} - u_{10} = v + e_h > u_{01} - u_{00} = v > 0$. The difference between the utility from continuing participation (u_{11}) and starting to participate (u_{10}) is the future benefit of participation and the effect of habituation. This difference is greater than the difference in utility from quitting and never participating which is the future benefit of participation. We assume that the system is stationary.

Consider the decision made by a partially naive current participant $(a_t = 1)$. She can either continue to participate or quit. She believes that if she chooses to continue participating $(a_{t+1} = 1)$, her expected continuation utility will be

$$W_{t+1}(a_{t+1} = 1 | a(\widetilde{\beta})^{t+2}, a_t = 1)$$
$$= u_{t+1}(a_{t+1} = 1 | a(\widetilde{\beta})^{t+2}, a_t = 1) + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)].$$
$$= u_{11} - \varepsilon_{t+1} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)].$$

If she quits $(a_{t+1} = 0)$, her expected continuation utility will be

$$W_{t+1}(a_{t+1} = 0 | a(\widetilde{\beta})^{t+2}, a_t = 1)$$
$$= u_{t+1}(a_{t+1} = 0 | a(\widetilde{\beta})^{t+2}, a_t = 1) + \widetilde{\beta}\delta E[W_{t+2}(\widetilde{\beta}, a_{t+1} = 0)].$$
$$= u_{01} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 0)].$$

She will choose to continue participating if her expected utility from continuing exceeds her expected utility from quitting

$$W_{t+1}(a_{t+1} = 1 | a(\widetilde{\beta})^{t+2}, a_t = 1) \geqslant W_{t+1}(a_{t+1} = 0 | a(\widetilde{\beta})^{t+2}, a_t = 1)$$

implying that

$$\varepsilon_{t+1} \leq \widetilde{\beta}\delta\{E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)] - E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 0)]\} + u_{11} - u_{01}.$$

Define

$$\Psi \equiv E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)] - E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 0)].$$

Ψ reflects the perceived net benefit of continuing relative to quitting. This individual's period-t self perceives that in period $t+1$, the probability of participation in physical activity conditional on participation in period t is

$$\widetilde{p}_1 = \Pr(\varepsilon_{t+1} \le \widetilde{\beta}\delta\Psi + u_{11} - u_{01})$$

The perceived future probability of participation depends on the relative size of the participation-specific cost shock, the net perceived benefits of participation, and the difference between the utility from continued participation and quitting.

Using the same logic, we can solve for the perceived probability of participation in period $t+1$ conditioned on current non-participation $a_t = 0$. The period $t + 1$ self is perceived to choose $a_{t+1} = 1$ if $W_{t+1}(a_{t+1} = 1|a(\widetilde{\beta})^{t+2}, a_t = 0) \ge W_{t+1}(a_{t+1} = 0|a(\widetilde{\beta})^{t+2}, a_t = 0)$, i.e.,

$$u_{10} - \varepsilon_{t+1} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)] \ge u_{00} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 0)]$$

So, this individual's period-t self perceives that in period $t+1$, the probability of participation in physical activity conditioned on non-participation in period t is

$$\widetilde{p}_0 = \Pr(\varepsilon_{t+1} \le \widetilde{\beta}\delta\Psi + u_{10} - u_{00}).$$

Note that the difference between $\widetilde{p}_0$ and $\widetilde{p}_1$ is $u_{10} - u_{00}$ and $u_{11} - u_{01}$ which is e_h, or habituation.

Let H and h be the cumulative and density distribution function of ε, the participation cost shock. For the period t self, the perceived expected continuation utility in period $t+1$ for current participants ($a_t = 1$) is

$$E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] = \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \{u_{11} - \varepsilon_{t+1} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 1)]\}h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

$$+ \int_{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}}^{\infty} \{u_{01} + \widetilde{\beta}\delta E[W_{t+2}(a(\widetilde{\beta})^{t+3}, a_{t+1} = 0)]h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

$$= u_{01} + \widetilde{p}_1(\widetilde{\beta}\delta\Psi + u_{11} - u_{01}) - \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

The perceived expected continuation utility in period $t + 1$ for current non-participants ($a_t = 0$) is

$$E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)] = u_{00} + \widetilde{p}_0(\widetilde{\beta}\delta\Psi + u_{10} - u_{00}) - \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

Based on the perception of expected continuation utility given choices, the period t self will choose a_t to maximize

$$u_t(a_t|a(\widetilde{\beta})^{t+1}, a_{t-1}) + \beta\delta E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t)].$$

If $a_{t-1} = 1$, the period t self will choose $a_t = 1$ if

$$u_t(a_t = 1|a(\widetilde{\beta})^{t+1}, a_{t-1} = 1) + \beta\delta E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] \geqslant u_t(a_t = 0|a(\widetilde{\beta})^{t+1}, a_{t-1} = 1) + \beta\delta EW_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)].$$

or

$$\varepsilon_t \leq \beta\delta\{E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] - E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)]\} + u_{11} - u_{01}.$$

An individual will continue to participate in physical activity as long as the total expected utility generated from participation exceeds the cost shock associated with participation.

From the stationarity assumption, $\Psi = E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] - E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)]$. The actual probability that the period t self chooses to participate in period t conditional on $a_{t-1} = 1$ is

$$p_1 = \Pr(\varepsilon_t \leq \beta\delta\Psi + u_{11} - u_{01}) = H(\beta\delta\Psi + u_{11} - u_{01})$$

Using the same approach, we can derive the probability that the period t self chooses to participate in period t conditioned on $a_{t-1} = 0$

$$p_0 = \Pr(\varepsilon_t \leq \beta\delta\Psi + u_{10} - u_{00}) = H(\beta\delta\Psi + u_{10} - u_{00}).$$

Again, the actual probability of participation is p_1 for those who participated in physical activity in the previous period and p_0 for those who did not participate in the previous period. The perceived participation probability $\widetilde{p}_1$ and $\widetilde{p}_0$ will not equal the actual probability unless an individual is sophisticated and has $\widetilde{\beta} = \beta$.

3.2 Projection Bias on Habit Formation and Decay

We analyzed participation in physical activity with habit formation and naivete regarding present bias. Next we analyze the impact of projection bias regarding habit formation and decay. Projection bias refers to bias in predicting some future state: people tend to project their current behavior into the future, even though the true future state follows a predictable path (Loewenstein et al., 2003). We focus on the impact of projection bias on future costs of participation in physical activity, since costs represent an important barrier to participation. Projection bias affects decisions to start and continue to participate in important ways. People who engage in regular, or habitual, physical activity tend to underestimate the mental and physical effort needed to participate in physical activity when they are not habituated to physical activity; people who do not engage in regular physical activity tend to overestimate the mental and physical effort required to participate regularly in physical activity.

Specifically, let $\widehat{e}_{h1} \in [0, e_h]$ be the belief of individuals with $a_{t-1} = 1$ in period t about the cost of participation in physical activity in some period $k > t$ when $a_{k-1} = 0$, and $\widehat{e}_{h2} \in [0, e_h]$ be the belief of individuals with $a_{t-1} = 0$ in period t about the cost of participation in physical activity in a period $k > t$

when $a_{k-1} = 1$. We allow the projection bias to be asymmetric. In the following analysis, we assume for simplicity that individuals are sophisticated about their present bias.

We first investigate the projection bias of people who engage in regular participation in physical activity, an aspect that has not been examined as closely as the projection bias of people who do not engage in habitual physical activity. For an individual with $a_{t-1} = 1$, the period t self believes that the psychological and physical effort costs e_{t+1} will be $e - \widehat{e}_{h1}$ if he chooses $a_t = 0$, so he predicts that he will choose $a_{t+1} = 1$ if

$$u_{t+1}(a_{t+1} = 1 | \widehat{e}_{h1}, a_t = 0) + \beta \delta E W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 1)] \geqslant u_{t+1}(a_{t+1} = 0 | \widehat{e}_{h1}, a_t = 0) + \beta \delta E W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 0)]$$

or

$$\varepsilon_{t+1} \leq \beta \delta \{ E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 1)] - E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 0)] \} + \widehat{u_{10}} - u_{00}.$$

where $\widehat{u_{10}} = f(y_t - c_t) + g(l_t - T) - (e - \widehat{e}_{h1})$. The period t self with $a_{t-1} = 1$ predicts that the probability of participating in period $t + 1$ after choosing $a_t = 0$ will be $\widehat{p}_0 = \Pr(\varepsilon_{t+1} \leq \beta \delta \Psi_1 + \widehat{u_{10}} - u_{00})$ where $\Psi_1 \equiv E[W_{t+2}(\widehat{e}_{h1}, a_t = 1)] - E[W_{t+2}(\widehat{e}_{h1}, a_t = 0)]$, and the expected continuation utility after choosing $a_t = 0$ will be

$$E[W_{t+1}(\widehat{e}_{h1}, a_t = 0)] = \int_{-\infty}^{\beta \delta \Psi_1 + \widehat{u_{10}} - u_{00}} \{ \widehat{u_{10}} - \varepsilon_{t+1} + \beta \delta E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 1)] \} h(\varepsilon_{t+1}) d\varepsilon_{t+1}$$
$$+ \int_{\beta \delta \Psi_1 + \widehat{u_{10}} - u_{00}}^{\infty} \{ u_{00} + \widetilde{\beta} \delta E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 0)] h(\varepsilon_{t+1}) d\varepsilon_{t+1}.$$

This individual's period t self will predict the expected continuation utility if he chooses $a_t = 1$ to be

$$E[W_{t+1}(\widehat{e}_{h1}, a_t = 1)] = \int_{-\infty}^{\beta \delta \Psi_1 + u_{11} - u_{01}} \{ u_{11} - \varepsilon_{t+1} + \beta \delta E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 1)] \} h(\varepsilon_{t+1}) d\varepsilon_{t+1}$$
$$+ \int_{\beta \delta \Psi_1 + u_{11} - u_{01}}^{\infty} \{ u_{01} + \beta \delta E[W_{t+2}(\widehat{e}_{h1}, a_t = 0)] h(\varepsilon_{t+1}) d\varepsilon_{t+1}.$$

Based on these prediction, the period t self with $a_{t-1} = 1$ will choose $a_t = 1$ if

$$u_t(a_t = 1 | \widehat{e}_{h1}, a_{t-1} = 1) + \beta \delta E W_{t+1}(\widehat{e}_{h1}, a_t = 1)] \geqslant u_t(a_t = 0 | \widehat{e}_{h1}, a_{t-1} = 1) + \beta \delta E W_{t+1}(\widehat{e}_{h1}, a_t = 0)]$$

or

$$\varepsilon_t \leq \beta \delta \{ E[W_{t+1}(\widehat{e}_{h1}, a_t = 1)] - E[W_{t+1}(\widehat{e}_{h1}, a_t = 0)] \} + u_{11} - u_{01}.$$

Recall $\Psi_1 \equiv E[W_{t+1}(\widehat{e}_{h1}, a_t = 1)] - E[W_{t+1}(\widehat{e}_{h1}, a_t = 0)] = E[W_{t+2}(\widehat{e}_{h1}, a_t = 1)] - E[W_{t+2}(\widehat{e}_{h1}, a_t = 0)]$ due to the stationarity assumption. The probability of participating in period t for individuals with $a_{t-1} = 1$ will be $p_1 = \Pr(\varepsilon_t \leq \beta \delta \Psi_1 + u_{11} - u_{01})$.

Next consider those individuals who are not habituated to regular participation in physical activity. These individuals enter the current period with $a_{t-1} = 0$, and believe that when they become habituated,

their effort will be $(e - \widehat{e}_{h2})$ where $\widehat{e}_{h2} \in [0, e_h]$. The smaller is $\widehat{e}_{h2}$, the larger the projection bias. In the extreme case, individuals may believe that participation in physical activity will never get any easier, even if they participate regularly $(\widehat{e}_{h2} = 0)$.

For an individual with $a_{t-1} = 0$, the period t self believes e_{t+1} will be $e - \widehat{e}_{h2}$ if he chooses $a_t = 1$, so he predicts that he will choose $a_{t+1} = 1$ if

$$u_{t+1}(a_{t+1} = 1|\widehat{e}_{h2}, a_t = 1) + \beta\delta EW_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)] \geqslant u_{t+1}(a_{t+1} = 0|\widehat{e}_{h2}, a_t = 1) + \beta\delta EW_{t+2}(\widehat{e}_{h2}, a_{t+1} = 0)]$$

or

$$\varepsilon_{t+1} \leq \beta\delta\{E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)] - E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 0)]\} + \widehat{u_{11}} - u_{01}.$$

where $\widehat{u_{11}} = v + f(y_t - c_t) + g(l_t - T) - (e - \widehat{e}_{h2})$. The period t self with $a_{t-1} = 0$ will predict that the probability of participating in period $t + 1$ after choosing $a_t = 1$ will be $\widehat{p}_1 = \Pr(\varepsilon_{t+1} \leq \beta\delta\Psi_2 + \widehat{u_{11}} - u_{01})$ where $\Psi_2 \equiv E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)] - E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 0)]$, and the expected continuation utility after choosing $a_t = 1$ will be

$$\begin{aligned} E[W_{t+1}(\widehat{e}_{h2}, a_t = 1)] &= \int_{-\infty}^{\beta\delta\Psi_2 + \widehat{u_{11}} - u_{01}} \{\widehat{u_{11}} - \varepsilon_{t+1} + \beta\delta E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)]\}h(\varepsilon_{t+1})d\varepsilon_{t+1} \\ &+ \int_{\beta\delta\Psi_2 + \widehat{u_{11}} - u_{01}}^{\infty} \{u_{01} + \beta\delta E[W_{t+2}(\widehat{e}_{h2}, a_t = 0)]h(\varepsilon_{t+1})d\varepsilon_{t+1}. \end{aligned}$$

This individual's period t self will predict the expected continuation utility if he chooses $a_t = 0$ to be

$$\begin{aligned} E[W_{t+1}(\widehat{e}_{h2}, a_t = 0)] &= \int_{-\infty}^{\beta\delta\Psi_2 + u_{10} - u_{00}} \{u_{10} - \varepsilon_{t+1} + \beta\delta E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)]\}h(\varepsilon_{t+1})d\varepsilon_{t+1} \\ &+ \int_{\beta\delta\Psi_2 + u_{10} - u_{00}}^{\infty} \{u_{00} + \beta\delta E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 0)]h(\varepsilon_{t+1})d\varepsilon_{t+1}. \end{aligned}$$

Based on these predictions, the period t self with $a_{t-1} = 0$ will choose $a_t = 1$ if

$$u_t(a_t = 1|\widehat{e}_{h2}, a_{t-1} = 0) + \beta\delta EW_{t+1}(\widehat{e}_{h2}, a_t = 1)] \geqslant u_t(a_t = 0|\widehat{e}_{h1}, a_{t-1} = 0) + \beta\delta EW_{t+1}(\widehat{e}_{h2}, a_t = 0)]$$

or

$$\varepsilon_t \leq \beta\delta\{E[W_{t+1}(\widehat{e}_{h2}, a_t = 1)] - E[W_{t+1}(\widehat{e}_{h2}, a_t = 0)]\} + u_{10} - u_{00}$$

Recall the assumption of stationarity $\Psi_2 \equiv E[W_{t+1}(\widehat{e}_{h2}, a_t = 1)] - E[W_{t+1}(\widehat{e}_{h2}, a_t = 0)] = E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 1)] - E[W_{t+2}(\widehat{e}_{h2}, a_{t+1} = 0)]$. The probability of participating in period t for individuals with $a_{t-1} = 0$ will be $p_0 = \Pr(\varepsilon_t \leq \beta\delta\Psi_2 + u_{10} - u_{00})$.

3.3 Model Predictions

The model developed above contains a large number of economic and behavioral factors that affect participation in physical activity. We summarize here the predictions of the impact of different factors on the likelihood of participation in physical activity. The derivations for these predictions are in the Appendix.

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Prediction 1 (habit formation): Given $e_h > 0$, an individual's probability of participating in physical activity in period t is higher if she participated in physical activity in period $t - 1$. ($p_1 > p_0$)

Prediction 2 (present bias): The probability of starting or continuing to participate in physical activity is higher for individuals who are less present-biased. ($\frac{\partial p_1}{\partial \beta} > 0$, and $\frac{\partial p_0}{\partial \beta} > 0$)

Prediction 3 (patience): The probability of starting or continuing to participate in physical activity is higher for individuals who are more patient. ($\frac{\partial p_1}{\partial \delta} > 0$ and $\frac{\partial p_0}{\partial \delta} > 0$)

Prediction 4 (income): The probability of starting or continuing to participate increases with disposable income if money exhibits declining marginal utility, and is not affected by income if utility is quasi-linear in money. ($\frac{\partial p_1}{\partial y} > 0$ and $\frac{\partial p_0}{\partial y} > 0$ if $f' > 0$, $f" < 0$; $\frac{\partial p_1}{\partial y} = 0$ and $\frac{\partial p_0}{\partial y} = 0$ if $f' > 0$ and $f" = 0$)

Prediction 5 (leisure time): The probability of starting or continuing to participate increases with leisure time if leisure exhibits declining marginal utility, and is not affected by leisure time if utility is quasi-linear in leisure. ($\frac{\partial p_1}{\partial l} > 0$ and $\frac{\partial p_0}{\partial l} > 0$ if $f' > 0$, $f" < 0$; $\frac{\partial p_1}{\partial l} = 0$ and $\frac{\partial p_0}{\partial l} = 0$ if $g' > 0$ and $g" = 0$)

Prediction 6 (naivete on perceived participation): The more naive the period t self, the higher the perceived probability of participating in physical activity in period $t + 1$. (Given $\beta, \frac{\partial \widetilde{p_1}}{\partial \widetilde{\beta}} > 0$ and $\frac{\partial \widetilde{p_0}}{\partial \widetilde{\beta}} > 0$.)

Prediction 7 (naivete on actual participation): The more naive the period t self about present bias in future periods (larger $\widetilde{\beta}$), the higher the (actual) probability of participating in physical activity in the current period. (Given β, $\frac{\partial p_1}{\partial \widetilde{\beta}} > 0$, and $\frac{\partial p_0}{\partial \widetilde{\beta}} > 0$.)

A naive individual's *perceived* participation probability will be higher than that of a sophisticated individual whether there is habit formation or not, but a naive individual's *actual* participation probability will be higher than that of a sophisticated individual only when there is habit formation effect and naive individual knows about it.[6]

When there is no habit formation, the actual current period participation probability is the same for sophisticated and naive individuals, only their perception of next period's participation differs. Naive individuals believe that their future period selves are more likely to participate in regular physical activity than their current period selves while sophisticated individuals know that their future period selves will behave just like their current period selves. With habit formation, the naive belief about future participation increases the probability of current period participation because current period participation leads to reduced participation-specific costs in the future. The more likely is participation in the future, the larger

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[6]In the absence of habit formation, $\frac{\partial \Omega}{\partial \widetilde{\beta}} = 0$ because the probability of participation is the same regardless of last period's choice. This means $\widetilde{p}_1 = \widetilde{p}_0$. In this case,

$$\frac{\partial \, \widetilde{p}_1}{\partial \widetilde{\beta}} = h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})(\delta\Psi + \frac{\partial \Psi}{\partial \widetilde{\beta}}\widetilde{\beta}\delta) = h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})\delta\Psi > 0$$

and $\frac{\partial \widetilde{p}_0}{\partial \widetilde{\beta}} = h(\widetilde{\beta}\delta\Psi + u_{10} - u_{00})\delta\Psi > 0$, while $\frac{\partial p_1}{\partial \widetilde{\beta}} = h(\beta\delta\Psi + u_{11} - u_{01})\beta\delta\frac{\partial \Psi}{\partial \widetilde{\beta}} = 0$ and $\frac{\partial p_0}{\partial \widetilde{\beta}} = h(\beta\delta\Psi + u_{10} - u_{00})\beta\delta\frac{\partial \Psi}{\partial \widetilde{\beta}} = 0$.

the benefit from current period participation. This is a case where naivety about present bias leads to a higher probability of a preferred choice by the long-run self.

How could sophistication lead to worse outcomes than naivete? Remember, in the model we rule out the possibility of any commitment devices. If individuals are allowed to use commitment devices, then sophisticated individuals, knowing their self-control problems, will be more likely to pre-commit their future selves to achieve the outcome their long-run selves would prefer. Naive individuals do not seek commitment devices because they are not aware of their future self-control problem.

Prediction 8 (projection bias on quitting) The larger the effect of projection bias on habit decay (bigger $\widehat{e}_{h1}$), the smaller the probability of continuing participation in the current period for individuals who participated in physical activity in the previous period. ($\frac{\partial p_1}{\partial \widehat{e}_{h1}} < 0$)

Incorrectly predicting that physical activity will be easier than it actually is when not habituated leads active people to underestimate the true value of keeping the good habit of regular participation in physical activity now. These people are overly optimistic about the power of past habituation associated with regular participation in physical activity.

Prediction 9 (projection bias on starting) The larger the impact of projection bias on habit formation (smaller $\widehat{e}_{h2}$), the smaller the probability of starting participation in the current period for individuals who did not participate in physical activity in the previous period. ($\frac{\partial p_0}{\partial \widehat{e}_{h2}} > 0$)

Incorrectly predicting that physical activity will be harder than it actually will be when habituated makes inactive people underestimate the true value of acquiring the good habit of participating regularly in physical activity. These people are too pessimistic about the power of habituation in regular participation in physical activity, and never start participating.

4 Empirical analysis of longitudinal participation decisions

We next analyze data on participation in physical activity from a longitudinal data set that repeatedly asked questions about participation in physical activity to the same individuals at regular intervals. This allows us to distinguish individuals who always, or never report participating in physical activity from individuals who sometimes report regular participation in physical activity and to identify former participants who quit, and former non-participants who start participating. The general approach is to assess the extent to which observed patterns of participation in physical activity in a large, nationally representative survey are consistent with the predictions of the model, and existing evidence in the empirical literature.

4.1 Estimation Strategy

We test some of the predictions of our model of participation in physical activity using data from the BHPS. These data were described in Section 2. We take two slightly different empirical approaches. First, we

analyze the decision to quit participating after engaging in regular participation (the $QUIT$ model) and the decision to start participating after being physically inactive (the $START$ model). As suggested by the theoretical model, habit formation (and decay) and potential projection bias create an asymmetry between quitting and starting.[7] Second, we explore the history of past participation on current participation to test the habit formation and decay effect.

4.1.1 Models of Starting and Quitting

We estimate separate probit models for starting or quitting regular participation in physical activity. In one case, the $QUIT$ model, the dependent variable y_i is equal to one if individual i reported quitting regular participation in physical activity later in the sample after earlier reporting regular participation. In the other case, the $START$ model, the dependent variable y_i equal to one if individual i reported starting regular participation in physical activity later in the sample after reporting inactivity earlier in the sample. y_i is equal to zero for individuals who reported continued regular participation in the $QUIT$ model and for those who reported continued inactivity in the $START$ model.

The probit models estimated take the form

$$y_i = f(\gamma, X_i, \varepsilon_i) \tag{1}$$

where X_i is a vector of covariates, γ a vector of unobserved parameters to be estimated, and ε_i an unobservable error term that captures other factors that affect individual's decisions about participation in physical activity. We assume that ε_i is distributed with mean zero and constant variance. $f(\cdot)$ is the cumulative distribution function of the standard normal distribution. We estimate γ using maximum likelihood and transform the estimates of γ into marginal effects that show the change in the conditional probability that $y_i = 1$ associated with a one unit change in each covariate. The vector of explanatory variables X_i contains the variables reflecting the demographic and economics conditions faced by each respondent that might affect the decision to participate in physical activity and proxy variables for present bias and other psychological conditions.

Many factors may explain participation in physical activity, some may be unobservable to econometricians. In order to control for unobservable heterogeneity, we restrict our sample to individuals appearing in the BHPS in all seven waves administered between 2000 and 2006. We also restrict the sample to individuals who were at least 25 years of age in 2000, and less than 50 years of age in 2006. This helps to control for the effects of school attendance and retirement decisions on the decision to participate in physical activity.

We extract a number of variables related to education, employment, income, and other factors from the BHPS that are frequently included in empirical models of participation in physical activity. Table 2 contains

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[7]Grignon (2009) also find present bias has different impact on starting and quitting smoking. Quitting smoking is hard because smoking brings instant gratification and delayed health benefits. Similarly, stating participation is hard because it involves current costs and delayed health benefits.

summary statistics for these variables. The average age of individuals in the sample in 2000 was 35. A little more than half of the sample of the sample are males and just under three quarters are married. About 17% had children under the age of 12 in the household during the sample period.

Table 2: Summary Statistics - Full Sample

	Mean	Standard dev.
Age in 2000	34.91	5.53
Married	0.724	0.447
Change in marital status	0.253	0.552
Children under 12	0.166	0.372
Male	0.564	0.496
Education: University Degree	0.288	0.453
Education: A Level	0.227	0.419
Education: O Level	0.288	0.453
Commute time, hours	0.295	0.277
Moved	0.701	0.966
Had new child	0.160	0.531
Employed during period	0.936	0.245
Total household income, 2000 (000s)	16.28	11.69
Average real hourly wage	7.308	5.691
Not enough leisure time	0.322	0.467
Credit card debt in 2000	0.281	0.450
No control over what happens in life	0.303	0.460
Smoker in 2000	0.289	0.453
Observations	2572	

We use three variables reflecting educational attainment: an indicator variable for individuals with a university degree or higher; an indicator variable for completion of the A Level (General Certificate of Education Advanced Level); and an indicator variable for completion of the O Level (Ordinary Level). Credentials equivalent to a university degree include a Higher National Diploma (HND) which is the equivalent to the first two years of a three year university degree, or a Higher National Certificate (HNC) which is a similar credential issued in Scotland, Wales and Northern Ireland. About 30% of the sample possess either a university degree or HND/HNC. The A Level is a secondary school level qualification that takes two years and requires passing an examination. The O Level is a subject-based qualification awarded as part of the General Certificate of Education (GCE) in England, Scotland, Wales and Northern Ireland. This is also an examination based credential that is less rigorous and in-depth than the A Level. About 23% of the sample

passed the A Level exams and 29% passed the O level. The omitted educational attainment category is individuals without a university degree, A Level or O level; these individuals make up about 20% of the sample.

During the study period, 94% of the sample was employed at some point. From Table 2, the average time commuting to work for individuals in the sample was about 30 minutes. The BHPS also asks respondents to assess the amount time available for leisure activities. A feeling that there is not enough leisure time serves as a general proxy for the presence of time constraints. 32% of the sample reported feeling they did not have enough leisure time. Total household income in 2000 was 16,279 pounds sterling.

The variables *moved*, *had new child*, and *change in marital status* reflect events that are disruptive, at least temporarily, to one's daily schedule and raise participation costs to some extent. Not all these events are unexpected, but the size of the effect of, say, a new child in the household, may be difficult to assess before the event occurs. A rather large percentage of the sample (70%) moved during the study period. A quarter of the sample had a change in marital status and 16% had a new child during the sample period.

A final group of control variables are proxies for present bias. The first proxy variable is an indicator variable for individuals who reported positive credit card debt 2000. Credit card debt has been found to be associated with present bias (Meier and Sprenger, 2010). The second proxy variable is an indicator for reported smoking in 2000. Smoking has been linked to present biased time preferences in previous research (Burks et al. (2012), Grignon (2009) and Kang and Ikeda (2013)). About 28-29% of the sample exhibit these behaviors.

We also include an indicator variable for individuals with weak locus of control. The BPHS contains a question that assesses the extent to which respondents feel they have control of their life, in other words a self-assessed locus of control proxy: "I feel that what happens to me is out of my control." We construct an indicator variable that is equal to one if an individual responded either "sometimes" or "often" when asked the frequency with which they have this feeling and zero otherwise.

4.1.2 History of Past Participation

Charness and Gneezy (2009) and Acland and Levy (2015) find evidence supporting the importance of habit formation in health club exercise. These studies randomly assign individuals into groups that receive or do not receive financial incentives to exercise in health clubs and track their attendance over time. They find a significant post-intervention attendance increase of the treated groups relative to the control groups.

The model developed above assumes that past participation reduces effort costs of current participation and predicts that past participation in physical activity increases the probability of current participation (Prediction 1). We lack access to a "natural experiment" that would randomly increase the benefit to exercise for some survey respondents in these data; but we observe participation decisions for each individual over a sufficiently long period of time. This allows us to undertake simple tests of the effect of habit formation

on current participation decisions, assuming past participation is partly driven by the realization of the stochastic period-specific participation cost shock.

These tests analyze decisions about participation in regular physical activity in 2006 when controlling for past participation decisions and other individual characteristics. First, we estimate Probit models of the general form

$$p_{i,2006} = \alpha_0 + \sum_{j=1}^{3} \alpha_j p_{i,2006-2j} + \gamma X_i + \varepsilon_i \tag{2}$$

where $p_{i,t}$ is an indicator variable that is equal to one if individual i participated regularly in physical activity in BHPS survey wave t and zero otherwise. $p_{i,t}$ reflects each individual's history of participation in regular physical activity throughout the sample period. X_i is a vector of individual economic and demographic characteristics measured in 2000, or in some cases over the 2000-2006 period. ε_i is an unobserved random error term capturing all other factors that affect the participation decision. The αs and γ are unobservable parameters to be estimated.

Alternative to the habit formation and decay hypothesis, an empirical correlation between past participation and current participation can purely because of unobserved personal traits. If there is no effect of habit formation and decay and past participation is correlated with current participation through time-invariant unobservable personal traits, then the coefficient on the three past participation variables should be the same. So, the personal traits hypothesis implies $\alpha_1 = \alpha_2 = \alpha_3$ while the habit formation and decay hypothesis implies $\alpha_1 > \alpha_2 > \alpha_3$.

Another hypothesis relates to learning through participation. If there is no habit formation but people generally over-estimate the true effort costs of participation, then actual participation in one period can lead them to learn about actual effort costs, increasing the probability of future participation. To investigate this alternative hypothesis, we break our sample into two subsamples. The first subsample includes individuals who reported regular participation in physical activity in both 2000 and 2002 ($p_{i,2000} = 1$ and $p_{i,2002} = 1$). This subsample contains 1,061 individuals. The second subsample includes individuals who did not report regular participation in physical activity in either 2000 or 2002 ($p_{i,2000} = 0$ and $p_{i,2002} = 0$). This subsample contains 760 individuals. The individuals in the first subsample had a relatively long history of past participation while the individuals in the second subsample had a relatively long history of non-participation. We argue that learning learning should not be very important for individuals in the first subsample because they participated in the recent past. However, learning might have an effect for individuals in the second subsample because these individuals have not been physically active for quite some time, and they may incorrectly predict the effort needed to participate in physical activity. We estimate Probit models

$$p_{i,2006} = \alpha_0 + \alpha_1 p_{i,2004} + \gamma X_i + \varepsilon_i. \tag{3}$$

The learning hypothesis implies $\alpha_1 = 0$ for the regression with the first subsample and $\alpha_1 > 0$ for the regression with the second subsample, while habit formation and decay implies $\alpha_1 > 0$ for both subsamples.

4.2 Results

Table 3 shows the marginal effects based on the parameter estimates from Equation (1) and estimated P-values for the $QUIT$ model. Some of the covariates are measured as of the beginning of the sample period in 2000 (age, total household income, credit card debt, and smoker), while others reflect outcomes over the entire sample period. Again, dependent variables equal to zero in this model reflect continuous participation in physical activity throughout the sample period; these individuals exhibit habituation to exercise. The model explains 6.3% of the observed variation in participation.

Table 3: Empirical Results - Probit Model for Quitting Regular Participation

Variable	Marginal Effect	p-value
Age in 2000	0.002	0.399
Married	-0.018	0.573
Change in marital status	0.061	0.014
Children under 12	0.118	0.012
Male	-0.030	0.383
Education: University Degree	-0.147	0.001
Education: A Level	-0.125	0.004
Education: O Level	-0.097	0.019
Commute time, hours	0.025	0.669
Moved	0.005	0.757
Had new child	-0.027	0.443
Employed during period	-0.162	0.013
Total household income, 2000 (000s)	-0.002	0.215
Average real hourly wage	0.004	0.258
Not enough leisure time	0.128	0.001
Credit card debt in 2000	0.027	0.394
No control over what happens	-0.039	0.211
Smoker in 2000	0.136	0.001
Observations	1131	
Pseudo R^2	0.063	

Table 4 shows the marginal effects based on the parameter estimates from Equation (1) and estimated P-values for the $START$ model. The model contains the same covariates as the $QUIT$ model shown in Table 3. As was the case with the $QUIT$, the model does not explain much of the observed variation in participation in physical activity, as the psuedo-R^2 is only 0.067.

4.2.1 Results on Present Bias

The model predicts that individuals' present bias decreases the probability of participation in physical activity (Prediction 2). Based on studies that link directly elicited time preference to outcomes, we use two variables to proxy present bias: an indicator variable for smoking in 2000 and an indicator variable for positive credit card debt in 2000.

Smoking involves current utility gain and long-run costs, in terms of health effects. Individuals with present bias may experience difficulties quitting smoking because they tend to postpone quitting. Grignon (2009) find present bias is not correlated with starting smoking but is negatively correlated with quitting smoking. The empirical link between present bias and smoking is also found by Burks et al. (2012) and Kang and Ikeda (2013). We expect that individuals who smoked in 2000 are more likely to have present bias, and are more likely to quit and less likely to start participating in physical activity later in the sample. We find that individuals who smoked in 2000 were 13.6% more likely to quit regular participation in physical activity in the following six years, and were 7.7% less likely to start being regularly physically active than non-smokers.

Meier and Sprenger (2010) establish an empirical link between accumulation of credit card debt and a directly elicited measure of present bias. We expect that individuals with credit card debt will be more present-biased than those who do not accumulate such debt, and therefore, would be more likely to quit participation and less likely to start participation. The results are mixed. We find that individuals with credit card debt in 2000 were almost 10% less likely to start participating regularly in physical activity over the next six years than those that did not have any credit card debt, but we did not find a relationship between credit card debt and quitting regular participation in physical activity.

Overall, the results, when combined with findings from the time preference literature, are consistent with Prediction 2. Less present bias is associated with a higher probability of an individual starting to participate in physical activity or continuing to participate, conditional on past participation.

4.2.2 Results on Habit Formation and Decay

Table 5 presents the results from Equations (2) and (3). The first two columns contain results using a sample of individuals who participated in physical activity in 2000 and 2002. The estimated coefficient on participation in 2004 is statistically significant and positive. This result implies that, even among people who had been participating in physical activity in 2000 and 2002, those who participated in 2004 were about 70% more likely to participate in 2006 than those who did not participate in 2004. Note that this result is conditioned on demographic, economic and psychological factors. We interpret $\hat{\alpha}_1 > 0$ in column (1) as evidence against learning because this subsample of individuals should have already learned the true effort costs or their tastes toward physical activity through their participation in 2000 and 2002, unless the learning process is very slow and takes longer than 4 years. We argue that $\hat{\alpha}_1 > 0$ in column (1) is consistent with habit formation and decay. Even for people who had unobservable personal traits to make them participate

Table 4: Empirical Results - Probit Model for Starting Regular Participation

Variable	Marginal Effect	p-value
Age in 2000	-0.013	0.001
Married	-0.017	0.668
Change in marital status	0.024	0.499
Children under 12	0.047	0.397
Male	-0.027	0.512
Education: University Degree	0.114	0.026
Education: A Level	-0.021	0.663
Education: O Level	-0.045	0.311
Commute time, hours	-0.140	0.047
Moved	0.032	0.072
Had new child	0.010	0.775
Employed during period	0.060	0.370
Total household income, 2000 (000s)	-0.001	0.930
Average real hourly wage	0.005	0.311
Not enough leisure time	-0.045	0.172
Credit card debt in 2000	-0.096	0.007
No control over what happens	-0.084	0.017
Smoker in 2000	-0.077	0.025
Observations	902	
Pseudo R^2	0.070	

in 2000 and 2002, had acquired the habit of regular participation, and potentially had learned the nature of physical activity, stopping in 2004 significantly reduces their probability of participating in 2006, suggesting that participating in physical activity is a rather delicate habit that decays quickly and requires careful maintenance.

Columns (3) and (4) in Table 5 show the results using the sample of individuals who did not participate in physical activity in 2000 or 2002. The estimated coefficient on participation in 2004 is statistically significant and positive. This result implies that, among people who did not participate in physical activity in 2000 or 2002, those who participated in 2004 were about 76% more likely to participate in 2006 than those who did not participate in 2004. We interpret $\hat{\alpha}_1 > 0$ in column (3) to be consistent with a combination of learning and habit formation. We do not know whether these individuals had participated before 2000 but it is safe to say that they had a relatively long recent history of non-participation right before 2004. Participating in 2004 may help them learn or form a habit, both of which could increase their probability of participating in 2006. The result suggests that encouraging people who have been inactive for a long time in the past to participate now may have a temporal externality through habit formation and learning. Compared to $\hat{\alpha}_1 > 0$ in column (1), the size of the point estimate in column (3) is only slightly bigger, suggesting that the effect of learning might be small compared to the effect of habit formation.

Columns (5) and (6) in Table 5 contain results using the entire sample of prime age individuals who appeared in every wave of the BHPS from 2000 to 2006. The estimated coefficient on the indicator variable for participation in 2004 ($\hat{\alpha}_1$), participation in 2002 ($\hat{\alpha}_2$), and participation in 2000 ($\hat{\alpha}_3$) are all positive and significantly different from zero. Suppose the unobservable personal traits that make people more or less likely to participate in physical activity is time invariant, then the *pure* personal traits hypothesis implies $\alpha_1 = \alpha_2 = \alpha_3$. The result ($\hat{\alpha}_1 > \hat{\alpha}_2 > \hat{\alpha}_3$) argues against the *pure* personal traits hypothesis. Note that it does not rule out the effect of time-invariant personal traits, but personal traits alone cannot fully explain the temporal correlation in participation. The result shows that more recent participation has a larger impact on current participation ($\hat{\alpha}_1 > \hat{\alpha}_2 > \hat{\alpha}_3$) and is consistent with the presence of habit formation and habit decay.

Overall, the results in Table 5 suggest learning and time invariant personal traits cannot fully explain the temporal pattern of participation in physical activity. The results are consistent with the hypothesis that participation in physical activity is a habit that is subject to significant decay if not maintained. The results are also consistent with positive serial correlation in the cost shocks associated with participation.

4.2.3   Other Socioeconomic and Psychological Factors

We now discuss the role of other demographic and psychological factors and compare the results in Table 3 to findings from cross-sectional studies. Studying physical activity behavior over time has the potential to provide some important insight to the episodic nature of physical activity that cannot be gleaned from cross-sectional or repeated cross-sectional data.

	Table 5: Tests of Habit Formation					
	$p_{00} = p_{02} = 1$		$p_{00} = p_{02} = 0$		Everyone	
	Param	P-val	Param	P-val	Param	P-val
Participated in 2004	0.693	0.001	0.757	0.001	0.811	0.001
Participated in 2002	—	—	—	—	0.495	0.001
Participated in 2000	—	—	—	—	0.352	0.001
Age in 2000	-0.007	0.454	-0.027	0.010	-0.013	0.019
Married	0.009	0.932	-0.051	0.676	0.006	0.928
Change in marital status	-0.056	0.515	0.020	0.851	-0.029	0.582
Children under 12	-0.603	0.001	0.063	0.710	-0.073	0.433
Male	-0.071	0.556	-0.037	0.778	-0.011	0.874
Ed: University Deg	0.485	0.001	-0.050	0.755	0.211	0.017
Ed: A Level	0.388	0.007	-0.138	0.370	0.162	0.059
Ed: O Level	0.383	0.006	-0.280	0.045	0.096	0.234
Commute time, hours	-0.204	0.291	-0.071	0.752	-0.043	0.718
Moved	-0.018	0.716	0.122	0.035	0.003	0.918
Had new child	0.143	0.256	0.102	0.339	0.067	0.283
Employed during period	0.646	0.002	-0.141	0.501	0.029	0.809
Income, 2000 (000s)	0.002	0.685	0.007	0.289	0.005	0.116
Average real hourly wage	-0.006	0.603	-0.008	0.598	-0.005	0.482
Not enough leisure time	-0.113	0.289	-0.121	0.246	-0.100	0.091
Credit card debt in 2000	-0.172	0.103	-0.178	0.119	-0.152	0.014
No control	0.111	0.292	-0.115	0.308	-0.034	0.585
Smoker in 2000	-0.311	0.006	-0.259	0.018	-0.122	0.051
Observations	1061		760		2572	
Pseudo R^2	0.098		0.106		0.198	

Dependent variable is equal to one if the individual reported regular participation in physical activity in 2006. Parameters estimated by Probit. Reported parameters are marginal effects.

The probability that an individual quits participation in physical activity at some point in the sample after previously reporting regular participation is not associated with age in this sample as the marginal effect, while positive and small, is not statistically different from zero. Contrary to the results for the $QUIT$ model, age did have an impact on decisions to start regular participation in physical activity. In this sample, older individuals in 2000 were 1.3% less likely to become physically active than younger individuals. The negative relationship between age and participation in physical activity from cross-sectional studies is likely due to reluctance to start rather than inclination to quit participation when people get older. This finding is important because the policy implication regarding the timing of policy intervention might be different. Our result suggests that for a particular individual, an intervention of the same size is more likely to induce participation when she is young.

Married individuals were no less likely to report quitting participation than singles, and males no less likely than females. The marginal effects for *married* and *male* were not statistically significant in the $START$ model just as they were not significant in the $QUIT$ model. These findings differ from the results of most, if not all, cross-sectional studies of physical activity. Most studies find that men are more likely to participate than women, and that married people are less likely to participate than single individuals.

Education has an important impact on the probability of quitting participation in physical activity. All individuals with a university degree, A level or O level credential were less likely to report quitting participation in physical activity and that the probability of quitting increases with less education. Those with a university degree were 14.5% less likely to quit participation in physical activity, compared to 12.2% for those with A level and 9.4% for those with O level. In contrast with the $QUIT$ model, education is not a particularly important factor influencing decisions to start participating in physical activity. The only education variable that is significant is *university degree*. Respondents with a university degree were 10% more likely to start participating in physical activity than those without a higher education credential.

Another variable commonly included in studies about participation in physical activity is the presence of children in the household. Results from cross-sectional studies are mixed with respect to the presence of children. Some studies find that the presence of very young children is negatively associated with participation but that the presence of "older" children in the household is positively associated with participation. The exact specification of this variable is driven by data, but most surveys ask questions reflecting the presence of children under the age of 12, as is the case with the BHPS, or very young children, usually under the age of 5. Our results indicate that the presence of children under the age of 12 was associated with a 12% greater probability of quitting regular participation but was not correlated with the probability of starting regularly participating in physical activity. Taken together the results from the $QUIT$ and the $START$ model, having young children appears to exert an overall negative pressure on physical activity participation in that an individual might quit when there are young children in the house, but this individual who quit due to young children in the house is not more likely to participate when there are no young children in the

house (e.g., children grow up). This result reinforces the importance of habit formation and decay in regular participation in physical activity.

Our findings regarding the role of labor market conditions and income differ somewhat from those of many studies using cross-sectional studies where income generally is positively related to participation and being employed is negatively related to participation. Most of the variables measuring labor market conditions, *employed during period*, *total household income*,[8] and *average real hourly wage* were not significantly different from zero, except *employed during period* in the *QUIT* model. Individuals who were employed during the sample period were 15.7% less likely to quit engaging in physical activity. We also include commuting time and wages in our regressions. The coefficient of wages was not significantly different from zero in either the *QUIT* or the *START* model indicating no relationship to the probability of quitting or starting participation. Individuals with a longer commute to work were less likely to start participating in physical activity but commuting time was not significantly correlated with quitting. Very few studies have measures of wages and even fewer, if any, include commuting time.

Next we investigate the role of major events that are likely to change people's lives, including moving, a change in marital status, and having a new child. Moving was not significant in the *QUIT* model but has a positive effect on the decision to start participating. A change in marital status was associated with a 6.4% increase in the probability of quitting but was not correlated with the probability of starting. Having a new child was not statistically significant in either the *QUIT* or *START* models.

We also find some interesting asymmetric impacts on quitting and starting with respect to the time constraint and internal locus of control. Individuals who felt they do not have enough leisure time were 12.8% more likely to quit engaging in physical activity than those who felt they had enough leisure time, but not having enough leisure time was not associated with the decision to start participation. Individuals who felt like they had no control over what happens in life, those with weak internal locus of control, were 8.4% less likely to start regularly participating in physical activity, but weak internal locus of control was not associated with the decision to quit participation.

5   Conclusions

A substantial number of individuals decided to start regular participation in common forms of sport and exercise like walking and swimming, or quit regular participation in these activities, over the six year period analyzed here. Documenting the frequency of starts, quits, and episodic participation in physical activity is important to further our understanding of this important health behavior. Most current evidence uses survey data collected at a single point in time, or repeated cross-sectional survey data over time, to develop evidence about factors associated with participation in physical activity. This evidence compares current participants to current non-participants. Since the surveys typically ask questions about participation in the last few

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[8]The same result was obtained when this variable was replaced with labor income and investment income.

weeks or months, little can be learned about the temporal nature of participation in physical activity.[9] Individuals who report not participating in physical activity in a cross sectional survey that asks about participation in the last month or six months could be individuals who never participate, or alternatively they could be episodic participants who happen to be in a period of non-participation. Our empirical analysis discover some interesting dynamic patterns in quitting and starting participating in physical activity that cross sectional data will not be able to reveal.

Previous research established the importance of present bias, habit formation, naivete and projection bias in gym contract choice and attendance decisions (Acland and Levy (2015), Charness and Gneezy (2009), DellaVigna and Malmendier (2006), and Garon et al. (2013)). We develop a dynamic discrete-time, discrete choice model incorporating these important behavioral factors and abstracting from the contracting aspects associated with health club membership and attendance. Our model helps to understand the dynamic decision to participate in general leisure time physical activity, which may not involve a complicated contract choice. The model generates a rich set of predictions regarding these behavioral factors and traditional economic factors. We find empirical results consistent with predictions regarding present-bias and habit formation using the BHPS, a nationally representative longitudinal sample. Predictions regarding naivete and projection bias are not directly testable with our data, but the theoretical implication suggests that these are important areas for future empirical investigation that may benefit policy making.

Many public policy initiatives focus on encouraging individuals to take up healthy habits like regular participation in physical activity. These programs often approach the lack of participation in physical activity as the result of lack of information, and provide information about the benefits of regular participation in physical activity. Implicitly, these campaigns assume that after learning about the future benefits of regular participation, inactive individuals will revise their forecasts and some may choose to start participating regularly. These campaigns ignore the possibility that self-control problems due to present bias, and misperception of the effect of habit formation and decay in participating in physical activity may act as barriers to starting regular participation. In addition, these campaigns are not targeted towards people who are currently active, implicitly assuming they will stay active. If self-control problems negatively affect both inactive and active individuals, then educating people about their present bias and the importance of developing commitment tools should be important. If participating in physical activity is a habit but decays, then it is important not only to educate inactive people about the habit formation effect to encourage starting, but also to educate active people about the habit decay effect to discourage quitting.

We acknowledge that our results must be understood in the context of the existing literature and our identification assumptions. Our data do not have directly elicited time preference measures or a clean "natural experiment" for habit formation. We draw from studies using directly elicited time preference measures and behavioral outcomes (Burks et al. (2012), Grignon (2009), Kang and Ikeda (2013), and Meier

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[9]Cavaco et al. (2014) develop evidence of episodic participation in exercise at ages 25, 35, 45, and at their current age, using retrospective data collected through an internet survey conducted in six European countries.

and Sprenger (2010)), and use smoking and the accumulation of credit card debt to proxy for present bias. Our test of the habit formation (and decay) hypothesis against the pure personal traits hypothesis and the learning hypothesis explores the history of past participation and assumes away positive serial correlation in unobservable participation shocks. We believe that the theoretical model and empirical analysis can inspire additional empirical investigation to reach more definitive conclusions about the role of behavioral factors in the dynamic decision to participate in physical activity for general populations.

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Appendix

Derivation of Predictions

1. Habit formation

$$p_1 - p_0 = H(\beta\delta\Psi + u_{11} - u_{01}) - H(\beta\delta\Psi + u_{10} - u_{00})$$
$$= H(\beta\delta\Psi + u_{10} - u_{00} + e_h) - H(\beta\delta\Psi + u_{10} - u_{00}) > 0.$$

$$\frac{\partial p_1}{\partial \delta} = h(\beta\delta\Psi + u_{11} - u_{01})(\beta\Psi + \frac{\partial\Psi}{\partial\delta}) > 0$$
$$\frac{\partial p_0}{\partial \delta} = h(\beta\delta\Psi + u_{10} - u_{00})(\beta\Psi + \frac{\partial\Psi}{\partial\delta}) > 0$$
$$\frac{\partial p_1}{\partial \beta} = h(\beta\delta\Psi + u_{11} - u_{01})(\delta\Psi + \beta\delta\frac{\partial\Psi}{\partial\beta}) > 0$$
$$\frac{\partial p_0}{\partial \beta} = h(\beta\delta\Psi + u_{10} - u_{00})(\delta\Psi + \beta\delta\frac{\partial\Psi}{\partial\beta}) > 0$$

2. Present Bias: See text.

3. Patience: See text.

4. Income

$$\frac{\partial p_1}{\partial y} = h(\beta\delta\Psi + u_{11} - u_{01})[\beta\delta\frac{\partial\Psi}{\partial y} + \frac{\partial(u_{11} - u_{01})}{\partial y}]$$

and

$$\frac{\partial\Psi}{\partial y} = -\frac{\frac{\partial\Omega}{\partial y}}{\frac{\partial\Omega}{\partial\Psi}} = 0$$

and

$$\frac{\partial(u_{11} - u_{01})}{\partial y} = 0$$

if $f(y) = k_y y$. Also, if $f' > 0$, $f'' < 0$, then $\frac{\partial(u_{11}-u_{01})}{\partial y} = \frac{\partial(u_{10}-u_{00})}{\partial y} = f'(y - c) - f'(y) > 0$, and

$$\frac{\partial\Omega}{\partial y} = -\widetilde{\beta}\delta(\frac{\partial\widetilde{p_1}}{\partial y} - \frac{\partial\widetilde{p_0}}{\partial y})\Psi - \frac{\partial\widetilde{p_1}}{\partial y}(u_{11} - u_{01}) + \frac{\partial\widetilde{p_0}}{\partial y}(u_{10} - u_{00}) + \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi+u_{11}-u_{01}}\varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial y}$$
$$- \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi+u_{10}-u_{00}}\varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial y} - \widetilde{p_1}\frac{\partial(u_{11}-u_{01})}{\partial y} + \widetilde{p_0}\frac{\partial(u_{10}-u_{00})}{\partial y}$$
$$= (\widetilde{p_0} - \widetilde{p_1})[f'(y - c) - f'(y)] < 0$$

Therefore, $\frac{\partial\Psi}{\partial y} = -\frac{\frac{\partial\Omega}{\partial y}}{\frac{\partial\Omega}{\partial\Psi}} > 0$ and $\frac{\partial p_1}{\partial y} > 0$. Using the same method $\frac{\partial p_0}{\partial y} = h(\beta\delta\Psi + u_{10} - u_{00})[\beta\delta\frac{\partial\Psi}{\partial y} + \frac{\partial(u_{10}-u_{00})}{\partial y}] > 0$ if $f' > 0$, $f'' < 0$, and $\frac{\partial p_0}{\partial y} = 0$ if $f' > 0$ and $f'' = 0$.

5. Leisure time

The derivation of this prediction is omitted as it follows the same procedure as the derivation of the income effect.

6./7. Naivete

From above, $\widetilde{p}_1 = \Pr(\varepsilon_{t+1} \le \widetilde{\beta}\delta\Psi + u_{11} - u_{01})$. It follows that

$$\frac{\partial \widetilde{p}_1}{\partial \widetilde{\beta}} = h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})(\delta\Psi + \frac{\partial\Psi}{\partial\widetilde{\beta}}\widetilde{\beta}\delta).$$

Since naivety increases the probability future participation, the perceived net benefit of continuing participation is positive, $\Psi = E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] - E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)] > 0$, because $a_t = 1$ generates more utility than $a_t = 0$ regardless of a_{t+1}.

Next, we show that $\frac{\partial\Psi}{\partial\widetilde{\beta}} > 0$. Partial naivety increases the perceived net benefit of future participation. From the stationarity assumption

$$\Psi = E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 1)] - E[W_{t+1}(a(\widetilde{\beta})^{t+2}, a_t = 0)]$$

$$= u_{01} - u_{00} + \widetilde{\beta}\delta(\widetilde{p}_1 - \widetilde{p}_0)\Psi + \widetilde{p}_1(u_{11} - u_{01}) - \widetilde{p}_0(u_{10} - u_{00})$$

$$- \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1} + \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

Rearranging this equation

$$[1 - \widetilde{\beta}\delta(\widetilde{p}_1 - \widetilde{p}_0)]\Psi - \widetilde{p}_1(u_{11} - u_{01}) + \widetilde{p}_0(u_{10} - u_{00}) + \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}$$

$$- \int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1} = u_{01} - u_{00} = v$$

Define the left side of the above equation as Ω. Differentiating Ω with respect to Ψ

$$\frac{\partial\Omega}{\partial\Psi} = [1 - \widetilde{\beta}\delta(\widetilde{p}_1 - \widetilde{p}_0)] - \widetilde{\beta}\delta(\frac{\partial\widetilde{p}_1}{\partial\Psi} - \frac{\partial\widetilde{p}_0}{\partial\Psi})\Psi - \frac{\partial\widetilde{p}_1}{\partial\Psi}(u_{11} - u_{01}) + \frac{\partial\widetilde{p}_0}{\partial\Psi}(u_{10} - u_{00})$$

$$+ \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial\Psi} - \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial\Psi}$$

$$= [1 - \widetilde{\beta}\delta(\widetilde{p}_1 - \widetilde{p}_0)] - \widetilde{\beta}\delta h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})(\widetilde{\beta}\delta\Psi + u_{11} - u_{01}) + \widetilde{\beta}\delta h(\widetilde{\beta}\delta\Psi + u_{10} - u_{00})(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})$$

$$+ \widetilde{\beta}\delta h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})(\widetilde{\beta}\delta\Psi + u_{11} - u_{01}) - \widetilde{\beta}\delta h(\widetilde{\beta}\delta\Psi + u_{10} - u_{00})(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})$$

$$= 1 - \widetilde{\beta}\delta(\widetilde{p}_1 - \widetilde{p}_0) > 0$$

Differentiating Ω with respect to $\widetilde{\beta}$

$$\frac{\partial \Omega}{\partial \widetilde{\beta}} = -\delta(\widetilde{p}_1 - \widetilde{p}_0)]\Psi - \widetilde{\beta}\delta(\frac{\partial \widetilde{p}_1}{\partial \widetilde{\beta}} - \frac{\partial \widetilde{p}_0}{\partial \widetilde{\beta}})\Psi - \frac{\partial \widetilde{p}_1}{\partial \widetilde{\beta}}(u_{11} - u_{01}) + \frac{\partial \widetilde{p}_0}{\partial \widetilde{\beta}}(u_{10} - u_{00})$$

$$+ \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial \widetilde{\beta}} - \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial \widetilde{\beta}}$$

$$= -\delta(\widetilde{p}_1 - \widetilde{p}_0)]\Psi - \left[\frac{\partial \widetilde{p}_1}{\partial \widetilde{\beta}}(\widetilde{\beta}\delta\Psi + u_{11} - u_{01}) - \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial \widetilde{\beta}} \right]$$

$$+ \left[\frac{\partial \widetilde{p}_0}{\partial \widetilde{\beta}}(\widetilde{\beta}\delta\Psi + u_{10} - u_{00}) - \frac{\int_{-\infty}^{\widetilde{\beta}\delta\Psi + u_{10} - u_{00}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1}}{\partial \widetilde{\beta}} \right]$$

$$= -\delta(\widetilde{p}_1 - \widetilde{p}_0)]\Psi < 0$$

Using the implicit function theorem

$$\frac{\partial \Psi}{\partial \widetilde{\beta}} = -\frac{\frac{\partial \Omega}{\partial \widetilde{\beta}}}{\frac{\partial \Omega}{\partial \Psi}} > 0.$$

Therefore,

$$\frac{\partial \widetilde{p}_1}{\partial \widetilde{\beta}} = h(\widetilde{\beta}\delta\Psi + u_{11} - u_{01})(\delta\Psi + \frac{\partial \Psi}{\partial \widetilde{\beta}}\widetilde{\beta}\delta) > 0$$

and

$$\frac{\partial \widetilde{p}_0}{\partial \widetilde{\beta}} = h(\widetilde{\beta}\delta\Psi + u_{10} - u_{00})(\delta\Psi + \frac{\partial \Psi}{\partial \widetilde{\beta}}\widetilde{\beta}\delta) > 0.$$

Naivety also affects actual current participation in physical activity. This follows because

$$\frac{\partial p_1}{\partial \widetilde{\beta}} = h(\beta\delta\Psi + u_{11} - u_{01})\beta\delta\frac{\partial \Psi}{\partial \widetilde{\beta}} > 0$$

and

$$\frac{\partial p_0}{\partial \widetilde{\beta}} = h(\beta\delta\Psi + u_{10} - u_{00})\beta\delta\frac{\partial \Psi}{\partial \widetilde{\beta}} > 0$$

8. Projection bias on quitting or continuing

Under the assumption of stationarity,

$$\Psi_1 \equiv E[W_{t+1}(\widehat{e}_{h1}, a_t = 1)] - E[W_{t+1}(\widehat{e}_{h1}, a_t = 0)] = E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 1)] - E[W_{t+2}(\widehat{e}_{h1}, a_{t+1} = 0)].$$

The stationary condition above can be rewritten

$$[1 - \beta\delta(p_1 - \widehat{p}_0)]\Psi_1 - p_1(u_{11} - u_{01}) + \widehat{p}_0(\widehat{u_{10}} - u_{00}) + \int_{\widetilde{\beta}\delta\Psi_1 + \widehat{u_{10}} - u_{00}}^{\beta\delta\Psi_1 + u_{11} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1} = v.$$

This relationship requires additional attention, as it describes the participation decision under projection bias. Define Ω_1 as the left hand side of the above equation and take the derivative with respect to Ψ_1

$$\frac{\partial \Omega_1}{\partial \Psi_1} = 1 - \beta\delta(p_1 - \widehat{p}_0) > 0$$

To see the effect of habituation in this context, differentiate Ω_1 with respect to $\widehat{e}_{h1}$

$$\frac{\partial \Omega_1}{\partial \widehat{e}_{h1}} = \beta\delta\Psi_1 \frac{\partial \widehat{p}_0}{\partial \widehat{e}_{h1}} + \frac{\partial \widehat{p}_0}{\partial \widehat{e}_{h1}}(\widehat{u_{10}} - u_{00}) + \widehat{p}_0 \frac{\partial(\widehat{u_{10}} - u_{00})}{\partial \widehat{e}_{h1}} - (\widetilde{\beta}\delta\Psi_1 + \widehat{u_{10}} - u_{00})h(\widetilde{\beta}\delta\Psi_1 + \widehat{u_{10}} - u_{00})\frac{\partial(\widehat{u_{10}} - u_{00})}{\partial \widehat{e}_{h1}}$$

$$= \widehat{p}_0 > 0$$

Using the implicit function theorem

$$\frac{\partial \Psi_1}{\partial \widehat{e}_{h1}} = -\frac{\frac{\partial \Omega_1}{\partial \widehat{e}_{h1}}}{\frac{\partial \Omega_1}{\partial \Psi_1}} < 0.$$

Therefore, $\frac{\partial p_1}{\partial \widehat{e}_{h1}} = h(\beta\delta\Psi_1 + u_{11} - u_{01})\beta\delta\frac{\partial \Psi_1}{\partial \widehat{e}_{h1}} < 0.$

9. Projection bias on starting

The stationarity assumption implies

$$[1 - \beta\delta(\widehat{p}_1 - p_0)]\Psi_2 - \widehat{p}_1(\widehat{u_{11}} - u_{01}) + p_0(\widehat{u_{10}} - u_{00}) + \int_{\widetilde{\beta}\delta\Psi_2 + u_{10} - u_{00}}^{\beta\delta\Psi_2 + \widehat{u_{11}} - u_{01}} \varepsilon_{t+1}h(\varepsilon_{t+1})d\varepsilon_{t+1} = v.$$

Define the left side of the above equation as Ω_2 and take the derivative with respect to Ψ_2

$$\frac{\partial \Omega_2}{\partial \Psi_2} = 1 - \beta\delta(\widehat{p}_1 - p_0) > 0$$

Differentiating Ω_2 with respect to $\widehat{e}_{h2}$ gives

$$\frac{\partial \Omega_2}{\partial \widehat{e}_{h2}} = -\beta\delta\Psi_2 \frac{\partial \widehat{p}_1}{\partial \widehat{e}_{h2}} - \frac{\partial \widehat{p}_1}{\partial \widehat{e}_{h2}}(\widehat{u_{11}} - u_{01}) - \widehat{p}_1 \frac{\partial(\widehat{u_{11}} - u_{01})}{\partial \widehat{e}_{h1}} + (\beta\delta\Psi_2 + \widehat{u_{11}} - u_{01})h(\beta\delta\Psi_2 + \widehat{u_{11}} - u_{01})\frac{\partial(\widehat{u_{11}} - u_{01})}{\partial \widehat{e}_{h1}}$$

$$= -\widehat{p}_1 < 0.$$

Finally, from the implicit function theorem

$$\frac{\partial \Psi_2}{\partial \widehat{e}_{h2}} = -\frac{\frac{\partial \Omega_2}{\partial \widehat{e}_{h2}}}{\frac{\partial \Omega_2}{\partial \Psi_2}} > 0.$$

From this expression, it follows that

$$\frac{\partial p_0}{\partial \widehat{e}_{h2}} = h(\beta\delta\Psi_2 + u_{10} - u_{00})\beta\delta\frac{\partial \Psi_2}{\partial \widehat{e}_{h2}} > 0.$$