Topic 23 – Self-control and neuroeconomics

Martin Kocher
University of Munich

Course in Behavioral and Experimental Economics

Preview of topic 23

- Neuroeconomics introduction
- Hyperbolic discounting
  + Laibson (1997)
  + McClure et al. (2004)
  + Albrecht et al. (2008)
- Hormons (Kosfeld et al., 2005)
- Field evidence (Malmendier and DellaVigna, 2006)
- Presentation: Dual self models of impulse control

Neuroeconomics

It was obviously only a question of time until economists got interested in the "ultimate" black box of (human) decision-making, the brain and the neuronal system.

"Economics is the science of choice."

A few applications as a teaser: Savings decisions, reward mechanisms, addiction problems, emotional responses, risk/uncertainty perception etc.

Neuroscience methods used in economics I

- Brain imaging (comparing an experimental task and a control task): EEG, PET, fMRI

  fMRI is the most popular method. It uses changes in magnetic properties due to blood oxygenation (the “BOLD” signal) to track blood flows in the brain. The BOLD signal reflects neuronal activity.

- Single-neuron measurement (with electrodes): usually with animals.
- EBS (electric brain stimulation): ditto

Neuroscience methods used in economics I-A

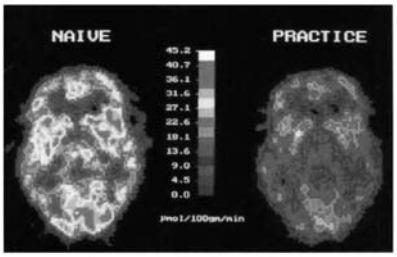


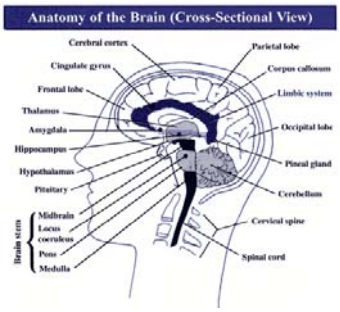
Figure 3. Regions of brain activation when first playing Tetris (left) and after several weeks of practice (right) (Haier et al. 1992).

Neuroscience methods used in economics II

- Psychopathology and brain damages: chronic mental illnesses, developmental disorders, lesions etc. and TMS (transcranial magnetic stimulation).

  TMS has the advantage of allowing causal inferences (in contrast to brain imaging) but is limited to the cortex and may have negative long-run) effects.

Neuroscience methods used in economics III



Neuroscience methods used in economics IV

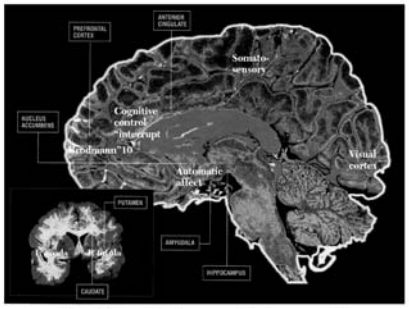
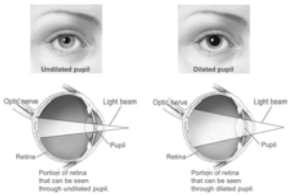


Figure 1. The human brain with some economically relevant areas marked.

Neuroscience methods used in economics V

- Psychophysical measurement: galvanic skin response, blood pressure, heart rate, pupil dilation, facial musculature.



Economic models that use neuroecon findings

- Dual-self models (e.g., Fudenberg and Levine, 2007): struggle between a long-run player and a short-run player.
- State-dependent models (e.g., Bernheim and Rangel, 2007, or Loewenstein and O'Donoghue, 2007): hot vs. cold states or deliberate processes and affective ones.
- Etc.

Use and "misuse"

- Simple correlations are not very helpful per se.

BUT

- Sometimes neuroeconomics allows to decide between different, competing theories.
- Sometimes the interplay and timing of affective and cognitive processes may be important in economic decision-making.
- And, of course, more relevant applications may develop over time (such as cryptographic methods in quantum physics).

Neural functioning and economics

TABLE 1
TWO DIMENSIONS OF NEURAL FUNCTIONING

	Cognitive	Affective
Controlled Processes ▪ serial ▪ effortful ▪ evoked deliberately ▪ good introspective access	I	II
Automatic Processes ▪ parallel ▪ effortless ▪ reflexive ▪ no introspective access	III	IV

Some economic applications

- Time discounting
- Ambiguity and risk
- Probability weighting
- Strategic thinking

- Hormones (e.g., oxytocin)
- Pupil dilation and lying

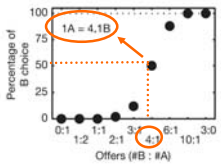
An illustration. The neuro-economics of savings decisions

Consider a situation where you can choose between the following two options:
- 10€ right now
- 11€ tomorrow

Now consider a situation where you can choose between the following two options:
- 10€ in one year
- 11€ in one year plus one day

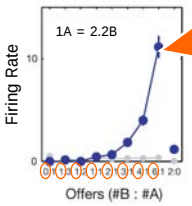
Reward (values in the brain)

- Thirsty monkeys choose between two different drinks (Padoa-Schioppa and Assad, 2006):
  - Drink A (water) = Preferred
  - Drink B (Kool-Aid) = Non-Preferred
- Behavioural indifference between A and B:



Value functions in decisions between certain outcomes

- Several offer types (B:A): 0:1, 1:3, 1:2, 1:1, 2:1, 3:1, 4:1, 6:1, 2:0 (sometimes also 10:1 and 3:0)
- Measure single-cell activity in orbitofrontal cortex during and shortly after reward-consumption



OFC-activity increases with increasing amount of fluid B. Encodes the **offer value** of B.

Value functions in decisions between certain outcomes

- Several offer types (B:A): 0:1, 1:3, 1:2, 1:1, 2:1, 3:1, 4:1, 6:1, 2:0 (sometimes also 10:1 and 3:0)
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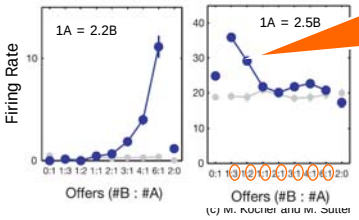
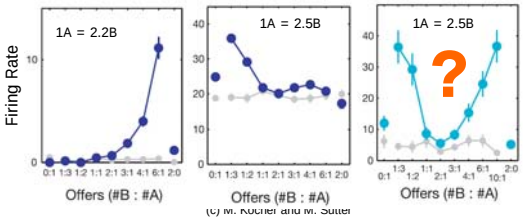


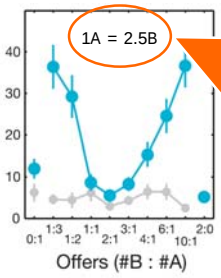
OFC-activity decreases with decreasing amount of fluid A. Encodes the **offer value** of A.

Value functions in decisions between certain outcomes

- Several offer types (B:A): 0:1, 1:3, 1:2, 1:1, 2:1, 3:1, 4:1, 6:1, 2:0 (sometimes also 10:1 and 3:0)
- Measure single-cell activity in orbitofrontal cortex during and shortly after reward-consumption



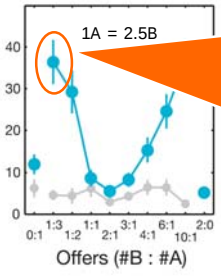
Value functions in decisions between certain outcomes



- 1A is 2.5x better than 1B (indifference relation)

(c) M

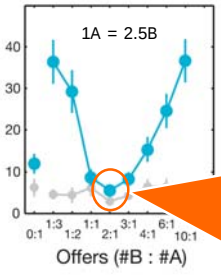
Value functions in decisions between certain outcomes



- 1A is 2.5x better than 1B (indifference relation)
- If monkey chooses between 1xB vs. 3xA (B:A = 1:3), option A is 7.5 better than option B. Hence, big relative difference in utilities!!

(c) M

Value functions in decisions between certain outcomes



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- If A and B are approx. equally good (B:A = 2:1), relative difference in utilities is minimal

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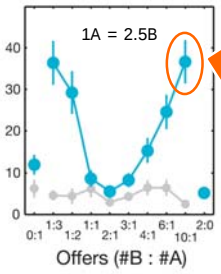
Value functions in decisions between certain outcomes



- 1A is 2.5x better than 1B (indifference relation)
- If monkey chooses between 1xB vs. 3xA (B:A = 1:3), option A is 7.5 better than option B. Hence, big relative difference in utilities!!
- If A and B are approximately equally good (B:A = 2:1), relative difference in utilities is minimal
- If monkey chooses between 1xA vs. 10xB, B is 4 times better than A. Relative D in utilities is big again! **Relative chosen value**

Value functions in decisions between certain outcomes

Relative Chosen Value

- OFC represents utility of the chosen option relative to the not chosen option
- Do OFC-neurons also reflect the numerical relation between the values? Does transitivity hold?
- Transitivity: If A >B and B>C, then A>C
- In the indifference terminology:
  - If A is 2.5 times better than B
  - and B is 3 times better than C
  - then A should be 7.5 times better than C
- Firing rate of OFC neurons reflects this numerical relation (Padoa-Schioppa, unpublished data)

Even simple rewards are actually more complicated

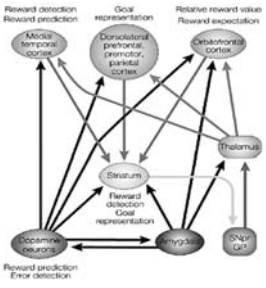


Figure 4. Hypothesized neural circuitry of reward processing (Schultz 2000).

Intertemporal decisions

The problem with savings decisions

Many subjects would choose the 10€ when they can get it immediately, but choose the 11€ when they receive it only in one year plus one day.

Such a choice pattern is dynamically inconsistent, because the time delay to get 1€ more is in both cases exactly one day.

The traditional approach of exponential discounting is insufficient for explaining such dynamically inconsistent choices.

Exponential and quasi-hyperbolic discounting

Exponential discounting assumes a steady discounting of future rewards by a factor δ (with $0 < \delta \leq 1$), irrespective of the delay.

$U_t = u_t + \delta\, u_{t+1} + \delta^2 u_{t+2} + \delta^3 u_{t+3} + \ldots$

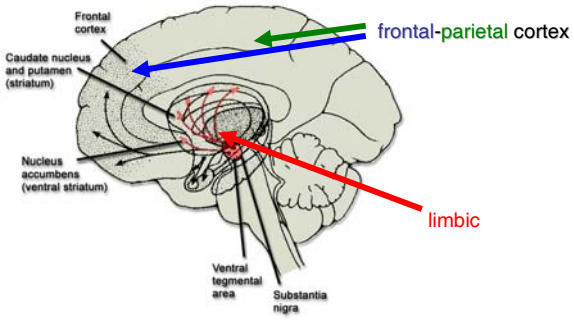
Quasi-hyperbolic discounting (Laibson, 1997) adds a preference for immediate gratification to the standard exponential discounting model. That means that all future rewards are additionally discounted by a factor β (with $0 < \beta \leq 1$).

$U_t = u_t + \beta\, [\delta\, u_{t+1} + \delta^2 u_{t+2} + \delta^3 u_{t+3} + \ldots]$

Examining quasi-hyperbolic discounting (McClure et al. 2004)

- Subjects choose between two rewards, e.g.
  - $15 gift certificate at time *d* or
  - $20 gift certificate at time *d`>d*
- Identify regions that show elevated activation only when immediacy is an option (i.e., *d=0* v. *d>0*): "β-regions".
- Identify regions that show elevated activation when making any intertemporal decision relative to benchmark of resting state: "δ-regions".

β-regions (limbic and para-limbic) vs. δ-regions (frontal-parietal cortex)



Savings for self and other (Albrecht et al. 2008)

The interplay of the β- and δ-regions seems to cause intertemporally inconsistent choices. Given this fact, we address the following *research questions*:

- Do subjects choose differently for *other* subjects?
- Do brain activities differ between deciding for SELF and deciding for OTHER?

Hypothesis: The limbic system should be elevated much less with decisions for OTHER. Hence, dynamically inconsistent choices should be reduced.

Methods

Subjects given a series of choices between
(€R at d) and (€R' at d') where R<R' and d<d'.

Free Response 2 sec 12 sec

d ∈ { Today, 2 weeks, 4 weeks }
d'-d ∈ { 2 weeks, 4 weeks }
R ∈ { 5€, 40€ }, Mean = 20€
(R'-R)/R ∈ {1%, 3%, 5%, 10%, 15%, 25%, 35%, 50%}

Conditions – SELF vs. OTHER

SELF
- Subjects made 40 decision for themselves.
- One decision was randomly chosen (at the end of the experiment) and paid according to the choice.
- If a future reward had been chosen, the subject got the money in cash only at the specified day.

OTHER
- Subjects made 40 decision for another person (in fact for someone in a later experiment at the respective day).
- One decision was randomly chosen (at the end of the experiment) and paid to the other person.
- The decision maker got a flat reward of 7€.

Procedure

Subjects were informed that the experiment would consist of two parts. The second part was only introduced after the first one had been finished.

14 subjects per treatment (SELF→OTHER or vice versa)

The average duration was about 20 minutes.

Experiments run at MPI Leipzig.

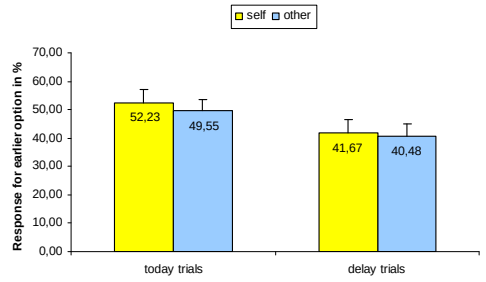
Brain activity was measured by fMRI.

Behavioral results

Overview of main results:

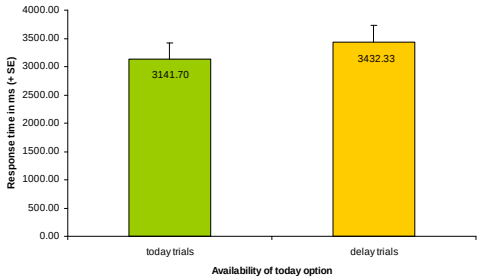
- The behavioral data do *not* differ between SELF and OTHER.
- Subjects choose more often the earlier reward and decide more quickly when the earlier reward is available *today*.
- Subjects get quicker and choose the later option more often in the course of the experiment (decrease of the immediacy effect).
- Subjects choose the earlier reward more often, the lower the percentage difference to the later reward.
- Subjects need more time for difficult decisions (with percentage differences from 5% to 25%) than for easy decisions (1%, 3%, 35%, 50%).

SELF vs. OTHER



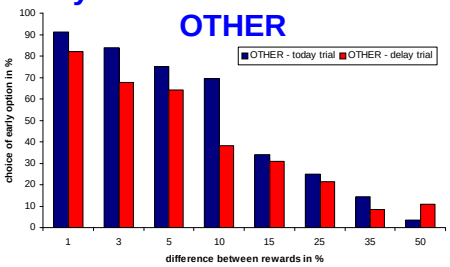
No significant difference between SELF and OTHER.
(today trials: early reward available today)
(delay trials: early reward in the future)

Response time



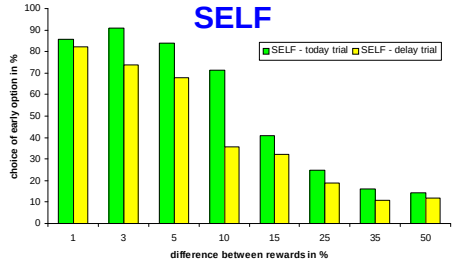
Subjects decide significantly faster when the early reward is available today ("today trials") than when the early reward is in the future ("delay trials").

Difference between early and delayed reward and choices in OTHER



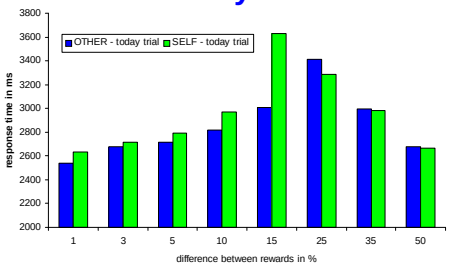
Subjects choose more often the early option the smaller the relative difference between early and delayed reward.

Difference between early and delayed reward and choices in SELF



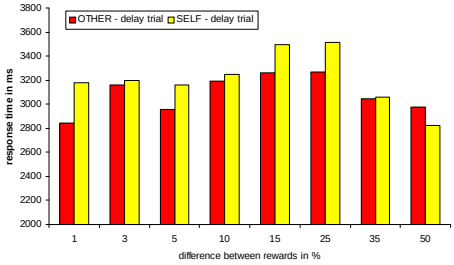
Subjects choose more often the early option the smaller the relative difference between early and delayed reward.

Difficulty of task and response time in today trials



Relatively easy tasks need less time than difficult (intermediate) ones in the today-trials.

Difficulty of task and response time in delay trials



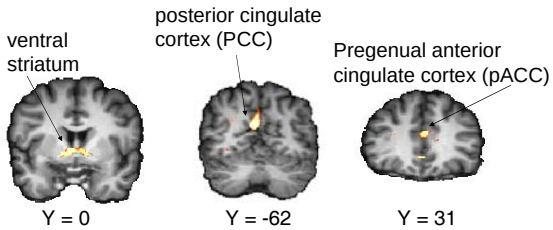
Hardly any relation between difficulty and response time in delay trials.

fMRI-results

Overview of main results:

- Replication of earlier results of McClure et al. (2004): With a “today”-option (in the SELF-condition) the limbic system is much more activated than when only future rewards have to be weighed.
- Decrease of limbic system-activation over time (in SELF).
- Hardly any activation of the limbic system in the OTHER-condition (with a “today”-option) ←→ as expected.

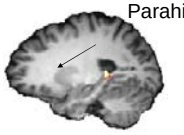
Today- vs. delay-trials in SELF



Highlighted areas show significant activation when “today” is an option → limbic system activated (not in delay-trials)
(SELF-condition as part 1 only)

Today- vs. delay-trials in OTHER

Parahippocampus



X = 22

Highlighted areas show significant activation when “today” is an option

The parahippocampus is usually ascribed to episodic memory and strategy retrieval.

(OTHER-condition as part 1 only)

Conclusions

Intertemporal choices for SELF have been shown to be a product of the interaction of limbic and frontal-parietal cortical systems (McClure et al., 2004; Albrecht et al., 2008).

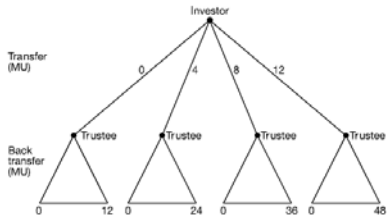
Albrecht et al. (2008) have shown that making decisions for OTHERs does *not* change the pattern of intertemporal choices.

Yet, the limbic system is practically not elevated when making decisions for OTHERs. So, it remains an open question why there are differences in brain activity, but not in economic decisions between SELF and OTHER.

Oxytocin increases trust in humans (Kosfeld et al., 2005)

- In non-human mammals, the neuropeptide oxytocin has a central role in general behavioral regulation, particularly in positive social interactions. Aside from its well-known physiological functions in milk letdown and during labor, oxytocin receptors are distributed in various brain regions associated with behavior including pair bonding, maternal care, sexual behavior, and the ability to form normal social attachments.
- Oxytocin seems to permit animals to overcome their natural avoidance of proximity and thereby facilitates approach behavior.
- Does it also promote prosocial approach behaviors – such as trust – in humans?

Oxytocin increases trust in humans (Kosfeld et al., 2005)



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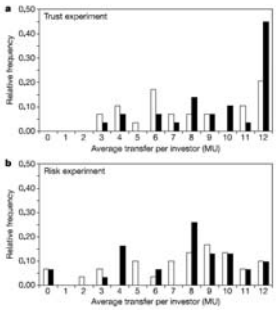
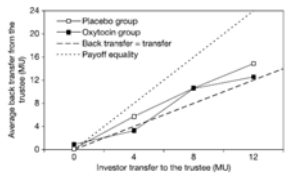


Oxytocin increases trust in humans (Kosfeld et al., 2005)

Table 1 | Median and average transfer behaviour of investors

	Trust experiment		Risk experiment	
	Oxytocin group	Placebo group	Oxytocin group	Placebo group
Mean average transfer (MU)	9.6	8.1	7.5	7.5
Median average transfer (MU)	10	8	8	8
Standard deviation of transfers (MU)	2.8	3.1	3.3	3.4
Number of observations	29	29	31	30



Paying not to go to the gym (Malmendier and DellaVigna, 2006)

- Contractual choice and attendance decisions in US health clubs.
- Contract offers: monthly contract ($70-85), annual contract ($850), pay-per-visit ($12 0r $10 in case one buys a 10-visit pass).
- Predictions:

Flat Rate versus Pay per Usage.—We consider first the choice at enrollment between a flat-rate contract $(L, 0, T)$ and a pay-per-visit contract $(0, p, T)$. Denote by δ the daily discount factor and by $E_F[v]$ the expected number of visits (over T days) under the flat-rate contract.

Prediction 1 (price per expected attendance at enrollment): *For agents who choose a flat-rate contract,*

$$\frac{L}{E_F[v]}\,\alpha(T) \le p. \tag{1}$$

Prediction 2 (attendance of monthly and annual members): *The average initial attendance of annual members is higher than the average initial attendance of monthly members:*

$$E_A[v] > E_M[v].$$

A third test for the standard model is whether consumers have rational expectations about their attendance.

Paying not to go to the gym (Malmendier and DellaVigna, 2006)

TABLE 1—EMPIRICAL FEATURES AND POSSIBLE EXPLANATIONS

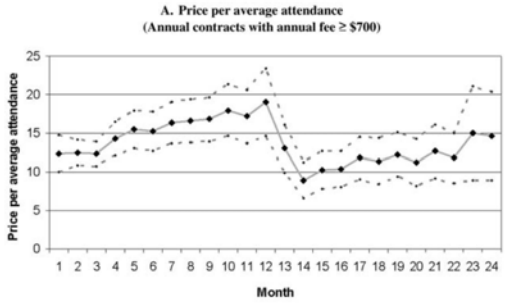
	Standard model	Trans. costs of payment per usage	Membership benefits per usage	Limited memory	Time increasing with sophistication	Time inconsist. with naiveté	Overestimation of future efficiency	Pressure
Finding 1 Price per average attendance = $17.27		Distaste of pay per usage	Membership benefits		Commitment	Commitment, overestimation of attendance	Overestimation of attendance	Pressure of salesman
Finding 2 Average attendance in months 2–4 higher in annual than monthly contract	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment	Sorting at enrollment
Finding 3 Users predict 9.50 monthly visits; actual monthly visits are 4.17						Overestimation of attendance	Overestimation of attendance	
Finding 4 Interval between last attendance and termination 2.31 full months		Distaste of pay per usage	Membership benefits	Forget to cancel		Overestimation of cancellation	Overestimation of cancellation	Pressure of salesman
Finding 5 Survival probability after 14 months 17 percent higher for monthly than for annual contract				Forget to cancel		Overestimation of cancellation	Overestimation of cancellation	Pressure of salesman
Finding 6 Average attendance 27 percent higher in second year for annual contract	Learning, sorting out	Learning, sorting out	Learning, sorting out	Learning, sorting out	Learning, sorting out	Learning, sorting out	Learning, sorting out	Learning, sorting out
Finding 7 Decreasing average attendance over time in monthly contract				Forget to cancel		Overestimation of cancellation	Overestimation of cancellation	Pressure of salesman
Finding 8 Positive correlation of price per average attendance and interval between last attendance and termination						Heterogeneity in naiveté	Heterogeneity in overconf.	

Paying not to go to the gym (Malmendier and DellaVigna, 2006)

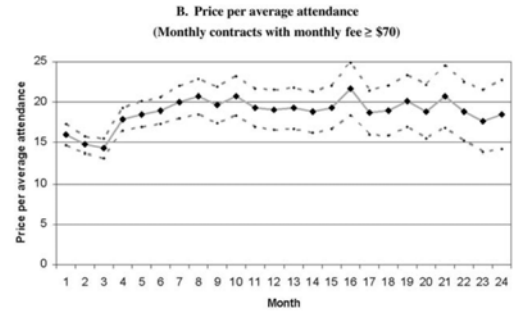
TABLE 3—PRICE PER AVERAGE ATTENDANCE AT ENROLLMENT

	Sample: No subsidy, all clubs		
	Average price per month (1)	Average attendance per month (2)	Average price per average attendance (3)
Users initially enrolled with a monthly contract			
Month 1	55.21 (0.80) $N = 829$	3.45 (0.13) $N = 829$	16.01 (0.66) $N = 829$
Month 2	60.65 (0.45) $N = 758$	5.46 (0.19) $N = 758$	14.76 (0.52) $N = 758$
Month 3	70.18 (1.05) $N = 753$	4.89 (0.18) $N = 753$	14.74 (0.58) $N = 753$
Month 4	81.79 (0.20) $N = 728$	4.57 (0.19) $N = 728$	17.89 (0.75) $N = 728$
Month 5	81.93 (0.25) $N = 701$	4.42 (0.19) $N = 701$	18.53 (0.80) $N = 701$
Month 6	81.94 (0.20) $N = 607$	4.32 (0.19) $N = 607$	18.95 (0.84) $N = 607$
Months 1 to 6	75.26 (0.27) $N = 866$	4.36 (0.14) $N = 866$	17.27 (0.54) $N = 866$
Users initially enrolled with an annual contract, who joined at least 14 months before the end of sample period			
Year 1	66.32 (0.37) $N = 145$	4.36 (0.36) $N = 145$	15.22 (1.25) $N = 145$

Paying not to go to the gym (Malmendier and DellaVigna, 2006)



Paying not to go to the gym



Paying not to go to the gym (Malmendier and DellaVigna, 2006)

Most important findings:

- Lots of people are worse of with the monthly payment scheme than with the pay-as-you-go scheme.
- Consumers with the monthly payment scheme are more likely to stay enrolled beyond one year than users choosing the annual contract.
- Most promising explanations: Overconfidence (over-estimation of future self-control), persuasion by health club employees.
- The “mistakes” entail a huge loss on the consumer side.