Economic Rationality Under Cognitive Load

Andreas C. Drichoutis[1] and Rodolfo M. Nayga, Jr.[2]

[1]Agricultural University of Athens
[2]University of Arkansas

Motivation

- Due attention to *heterogeneity* in economic behavior
- Accumulated research suggests that the expression of preferences depends on the cognitive resources available to the decision maker
  - Rustichini (2015): 'The role of intelligence in economic decision making'
  - People of high cognitive ability are found to be:
    - more risk-tolerant
    - more patient
    - less prone to anchoring effects
    - higher decision-making quality

How do people make decisions?

- Dual process theory
  - Two distinctively separate cognitive systems underlying thinking and reasoning
  - System 1: the impulsive and intuitive system
  - System 2: the reasoning system
  - Main differences of the systems in terms of: working memory capacity, consciousness in reasoning, automaticity, speed etc.
  - Working memory capacity is known to be highly correlated with reasoning ability
  - System 1 functions should be independent of such measures
  - System 2 functions should be related to measures of general intelligence

How do people make decisions?
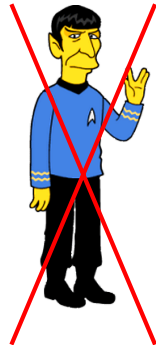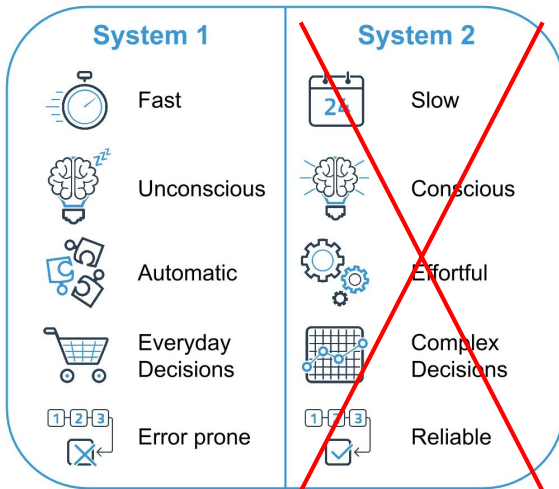
Cognitive load manipulations

- Can we mute Dr. Spock?
- Number memorization tasks concurrently with the task of interest (aka Cognitive load manipulations)
- Results from the literature:
  - reduces math solving ability and leads to poorer probability judgement
  - increases risk aversion
  - makes people more impatient
  - leads to poor food choices
  - generosity (but inconsistent results)
  - reduces strategic play and sophistication

Economic rationality

- Are the choices of people consistent with utility maximization?
- Employ the Generalized Axiom of Revealed Preference (GARP) to test whether the data $\mathbf{p}_i, \mathbf{x}_i$ can be rationalized by a utility function
- GARP requires that if $\mathbf{x}_i R \mathbf{x}_j$ (indirectly revealed) then it can't be that $\mathbf{x}_j R^0 \mathbf{x}_i$ (directly revealed)
- If data satisfy GARP, then data can be rationalized by a utility function

Economic rationality
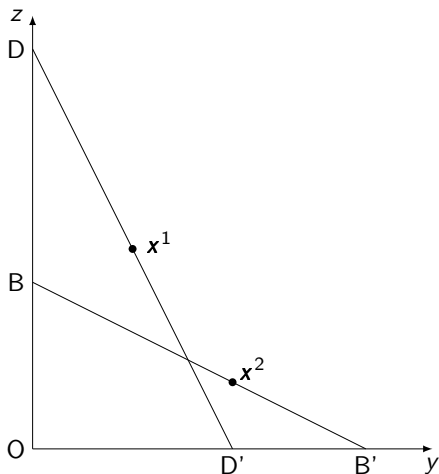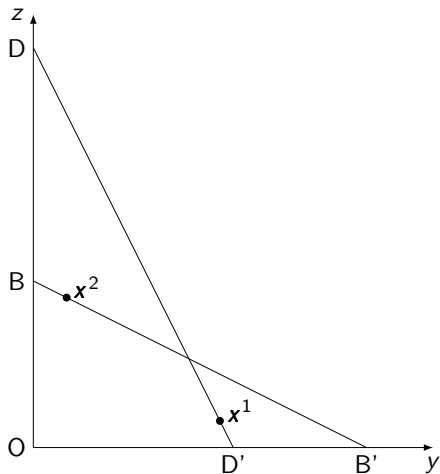
Research question

Assumption

Economic rationality is the deliberate product of reasoning.

Corollary

By impairing System 2:

- subjects will exhibit lower adherence to economic rationality
- choices are less likely to be consistent with the utility maximization model

Research question: Any support in the literature?

- Cognitive Reflection test:
    - A bat and a ball cost €1.10 in total. The bat costs €1.00 more than the ball. How much does the ball cost? (Hint: not €0.10)
    - If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? (Hint: not 100 min)
    - In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? (Hint: not 24 days)

- Higher scores in the CRT have been correlated with higher consistency with GARP

Experimental design

- Recruited 178 subjects from the undergrad population through ORSEE (May 2017)
- Subjects participated in group sessions although there was no interaction between them
- Computerized experiment (zTree) of about 60 min duration
- Show-up fees (€3)+ participation fees (€4); could also earn additional money (mean payouts=€13.05, S.D.=3.64, min=7, max=20.53)
- Before the treatment: measured the cognitive ability of all subjects using an abbreviated 9-item Raven's Standard Progressive Matrices (RSPM) test
- Basic demographic questions

Experimental design

- Subjects played 75 periods (one period randomly drawn and paid):
  - Memorize a number (shown for 4 sec)

Concurrent task $\left\{\begin{array}{l}\end{array}\right.$
  - Arithmetic (multiplication) task → (5 periods; earn €7 for correct answer in 11 sec)
  - Arithmetic (addition) task → (5 periods; earn €7 for correct answer in 11 sec)
  - Click-a-button task → (5 periods; earn €7 for correct answer in 11 sec)
  - Budget allocation task → (60 periods; allocate points between accounts; each account has a 50% chance; 1 point=€0.15)

  - Recall the number (earn €9 for correct answer in 10 sec)

Number memorization: Easy, LCL

Period **2 out of 75**

Remaining time [sec]: **2**

MEMORIZE task

Memorize this number: 8

Number memorization: Hard, HCL

Period **3 out of 75**

Remaining time [sec]: **2**
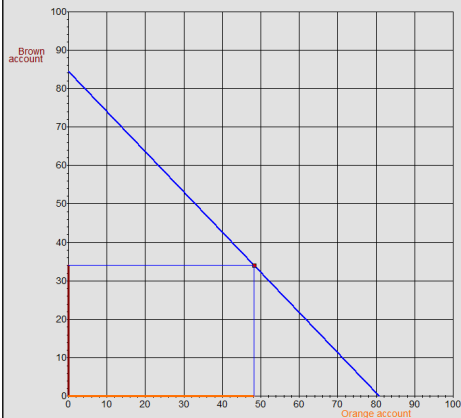
MEMORIZE task

Memorize this number: 41212961

Budget allocation task

AUA
AGRICULTURAL UNIVERSITY OF ATHENS

Arithmetic (multiplication) task

Period **6 out of 75**

Remaining time [sec]: **1**

MULTIPLICATION task

18 * 9 =

132	145
133	148
135	149
136	152
137	154
138	157
140	159
141	162

Arithmetic (addition) task

Click-a-button task

Number recall

Goodness-of-fit measures

- Empirically testing the GARP is problematic: the test is exact; no errors in measurement are allowed
- Goodness-of-fit measures allow to quantify the extent of violations
  - Afriat's CCEI: the degree required to relax a budget constrain to remove violations; takes values 0-1; 1=no violations; Varian suggests to use the 95% as critical level 'for sentimental reasons' [sic]
  - Houtman-Maks index (HMI): finding the largest subset of the data that is consistent with GARP
  - The Money Pump Index (MPI): an arbitrager that knows the choices of a subject that violates GARP could follow the opposite purchasing strategy and resell the goods to the subject at a profit
  - The Minimum Cost Index (MCI): Combines features of HMI and MPI

Recall the number

			HCL	LCL
	Combined over all tasks		33.64%	97.67%
Success rate	After...	Multiplication	8.97%	89.23%
		Addition	20.69%	96.92%
		Click-a-button	34.25%	98.46%
		Budget line	36.72%	98.37%

Recall the number: Logit regression

	Recall success	
Constant	1.878	(1.942)
Task: Budget line	1.656***	(0.166)
Task: Addition	1.119***	(0.194)
Task: Click-a-button	1.804***	(0.172)
HCL treatment	-4.692***	(0.168)
Demographics	Yes	
Period	0.009***	(0.002)
N	13350	
Log-likelihood	-4722.996	

Manipulation checks

		HCL	LCL	p-value
	Multiplication	39.08%	55.82%	<0.001
Success rate	Addition	85.98%	91.87%	0.005
	Click-a-button	99.77%	99.78%	0.975

Manipulation checks: Logit regression

	Success rate	
Constant	-3.135**	(1.454)
Task: Addition	2.262***	(0.138)
Task: Click-a-button	6.290***	(0.717)
HCL treatment	-0.670***	(0.142)
Demographics	Yes	
Period	0.142***	(0.040)
N	2670	
Log-likelihood	-910.171	

Economic rationality

Afriat's CCEI
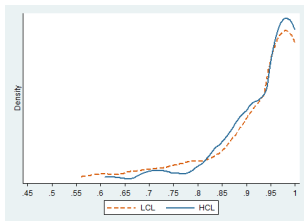
Minimum Cost index
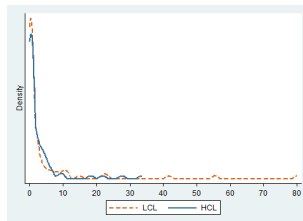
Houtman-Maks index

Money Pump index

23 out of 27 (85.2%)
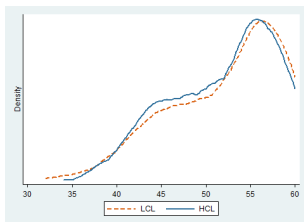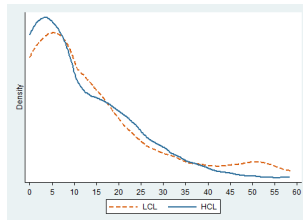
Economic rationality: Regressions

	Afriat's CCEI	HMI	MPI	MCI
Constant	0.733***	41.696***	1.321	16.692
	(0.135)	(9.464)	(0.933)	(14.043)
HCL treatment	0.015	-0.156	0.044	-1.245
	(0.015)	(1.044)	(0.099)	(1.549)
Demographics	Yes	Yes	Yes	Yes
Adjusted R^2	0.020	0.039		-0.003
Log-likelihood	-	-	-217.795	-

Was sample size large enough?

- What is the effect size that our sample size was powerful enough to detect?
- $n = \frac{2(z_{1-\alpha/2}+z_{1-\beta})^2}{(\frac{\mu_0-\mu_1}{\sigma})^2}$ where $\alpha = 0.05$ (Type I error) and $\beta = 0.20$ (Type II error) (Kupper and Hafner, 1989)
- μ_0 and μ_1 are the group means, with common variance σ^2
- Feed the formula with plausible values for $\mu_0 - \mu_1$ and σ^2 from past studies for ACCEI's and HMI (Choi et al., 2014)

		$\sigma = 0.12$	$\sigma = 0.14$	$\sigma = 0.16$
Afriat's CCEI	$d = 0.05$	90	123	161
	$d = 0.06$	63	85	112
	$d = 0.07$	46	63	82
	$d = 0.08$	35	48	63
	$d = 0.09$	28	38	50
	$d = 0.1$	23	31	40
		$\sigma = 2$	$\sigma = 2.2$	$\sigma = 2.4$
HMI	$d = 1$	63	76	90
	$d = 2$	16	19	23
	$d = 3$	7	8	10

Conclusions

- Impaired subjects' cognitive resources by taxing their working memory capacity
- Detrimental effects on math tasks (multiplication, addition); not on simple click-a-button
- No effect on consistency of choices with utility maximization
- Economic rationality can be attained even when working memory is taxed

Finale!

Thank you for your attention!