Game form recognition in preference elicitation, cognitive abilities and cognitive load

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Motivation

- Individuals have preferences over outcomes; independent on the context faced in a choice situation
- Competing theories: preferences are dependent or constructed from the context
- Choices are interpreted as evidence of non-standard preferences
- Cason and Plott (2014; JPE): mistakes potentially mask choices as evidence of non-standard preferences
  - Game Form Misconception (GFM): subjects appearing to have non-standard preferences, acting irrationally, or being affected by framing when these are really decision errors due to misconception

Cason and Plott (2014; JPE)

- Student subjects state offer prices for selling back to the experimenter an endowed card worth \$2
  - If offer price $\leq$ randomly drawn price $\rightarrow$ randomly drawn price
  - If offer price $>$ randomly drawn price $\rightarrow$ \$2
- Without training, repetition: only 16.7% of subjects chose offers $\$2 \pm 0.05$
- Not simply random departures from a correct understanding of the experimental task
- Mistakes arose from a misconception of the rules of the BDM mechanism: some subjects believed that the lowest offer wins and would be paid the offer price $\rightarrow$ they misconceived the BDM mechanism for a FPA

Follow up studies

- Bull, Courty, Doyon, Rondeau (2019; JEBO): additional test of GFM
  - If subjects do not bid optimally in the BDM because they misconceive it for a FPA, then the bid distributions of FP-GFM subjects should be similar in the BDM and FPA
  - Results:
    - The BDM is unreliable as a measure of preferences (only 7.9% of inexperienced subjects bid close to IV)
    - Subjects treated the two games as the same task when tasks were presented simultaneously; despite a warning was given about the tasks being different from each other → simultaneous presentation of the two tasks did not result in better GFR
    - FP-GFM is not a robust characterization of subjects' behavior

Related literature

- Why does the mechanism fail to reveal subjects' preferences?
- The concept of *obviously* strategy-proof mechanisms (Li, 2017; AER): although a mechanism may be strategy-proof (i.e., the weakly-dominant strategy of every bidder is to reveal their private values), the mechanism may be cognitively complex which would render it a *non-obviously* strategy-proof task
- e.g., the ascending clock auction and the SPA are equivalent but subjects are more likely to play the dominant strategy in the clock auction
- Complexity of a mechanism could vary between subjects depending on subjects' understanding $\rightarrow$ cognitive ability?

Related literature

- Neither the BDM or the FPA are OSP mechanisms; there is a widespread belief that the price mechanism of the FPA (paying what you bid) is simpler and more transparent than the price mechanism of the BDM (paying a random draw) $\rightarrow$ credibility
- Google Ads switched to an FPA from an SPA, citing reasons such as reducing complexity and increasing transparency for the switch
- "...it is generally held that the English auction is simpler for real-world bidders to understand than the sealed-bid second-price auction, leading the English auction to perform more closely to theory." (Ausubel, 2004; AER)

Task complexity & cognitive ability

- Cognitive limited agents are less likely to understand tasks with more complex mechanics
  - Choi et al. (2014, AER) the choices that some people make, may be different from the choices they would make if they had the skills or knowledge to make better decisions
  - Hassidim, Marciano, Romm, Shorrer (2017, AER) present some evidence that individuals misrepresent their preferences at a higher rate when they are of lower cognitive ability
  - Lee, Nayga, Deck, Drichoutis (2020, AJAE) find that subjects of higher cognitive ability tend to bid closer to their IV in a SPA; large overbids are vastly the typical behavior of subjects with low cognitive ability
  - Li (2017, AER) finds that subjects play the dominant strategy at significantly higher rates under the *obviously* strategy-proof ascending clock auction, compared to the SPA which is just strategy-proof (but not *obviously* strategy-proof)

Task complexity & cognitive ability

- The role of intelligence or cognitive ability in decision making
  - Branas et al. 2016; Rustichini 2015; Deck and Jahedi, 2015: more likely to play the NE in games, contribute more in a one-shot PGG, transfer larger share of a pie in a TG etc.; more risk-tolerant, more patient, and less prone to anchoring effects than those with lower cognitive ability

Research hypothesis

- We use both a BDM and a FPA in order to test that subjects in a BDM bid as if they participate in a FPA
- The two valuation tasks differ in their rules and complexity; subjects may require different cognitive resources to fully comprehend each of them

High cognitive load	Low cognitive load
BDM, FP	BDM, FP

- Temporarily tax cognitive resources
- Will be more hard for cognitive limited subjects to correctly identify the game form of the task
- Cognitively able subjects will be less affected
- The BDM will be affected more than the FP

Experimental design

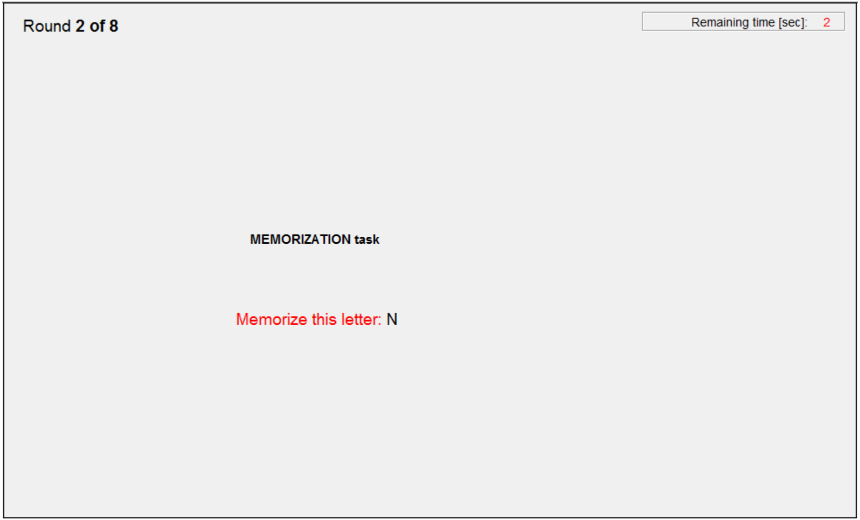
- Guided by sample size calculations, we recruited 269 subjects from the undergrad population through ORSEE; May 2018 at Laboratory of Behavioral and Experimental Economics Science (LaBEES-Athens); 65 subjects/cell
- Subjects participated in group sessions although there was no interaction between them
- Computerized experiment (zTree) of about 50 min duration
- Show-up fees + participation fees = €6; could also earn additional money (mean payouts=€10.60, S.D.=3.07, min=6, max=14)
- Before the treatment: measured the cognitive ability of all subjects using the Raven's Standard Progressive Matrices (RSPM) test (60 questions; 20 min on average)
- Basic demographic questions

Experimental design

	High cognitive load	Low cognitive load
BDM	70	66
FP	66	67

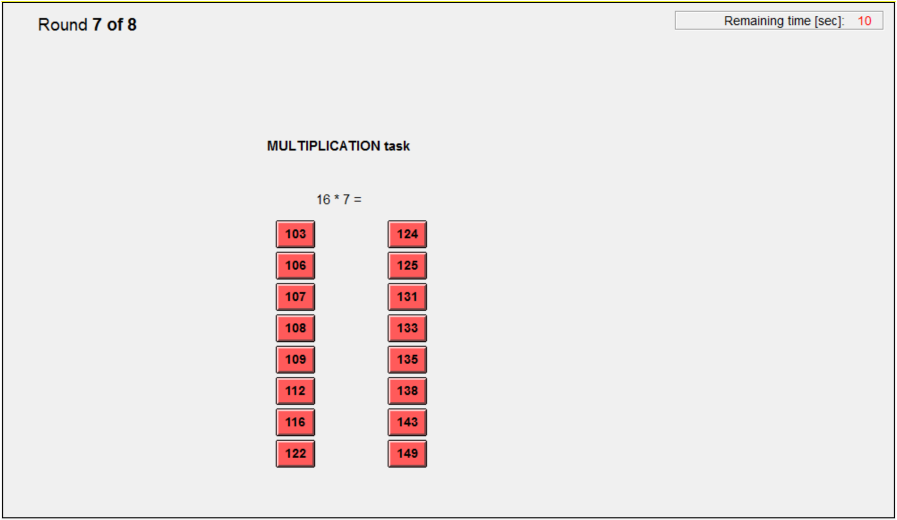
- Subjects played 8 periods (one period randomly drawn and paid):
  - Memorize a string (shown for 4 sec; Practice: Yes)
  - Concurrent task:
    - Arithmetic (multiplication) task → (2 periods; earn €5 for correct answer in 11 sec; Practice: Yes)
    - Arithmetic (addition) task → (2 periods; earn €5 for correct answer in 11 sec; Practice: Yes)
    - Click-a-button task → (2 periods; earn €5 for correct answer in 11 sec; Practice: No)
    - BDM/FP → (2 periods; sell a card valued at €5; Practice: No)
  - Recall the string (earn €8 for correct answer in 10 sec; Practice: Yes)

String memorization: Easy, LCL

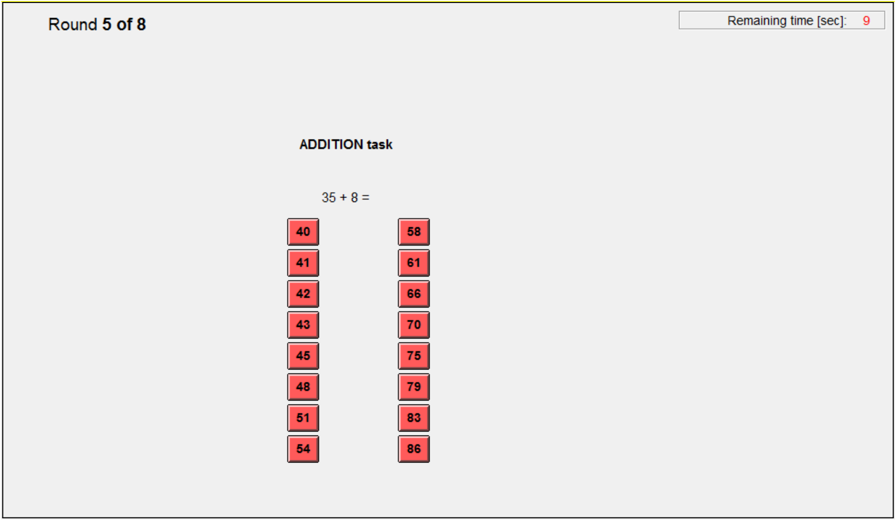


String memorization: Hard, HCL

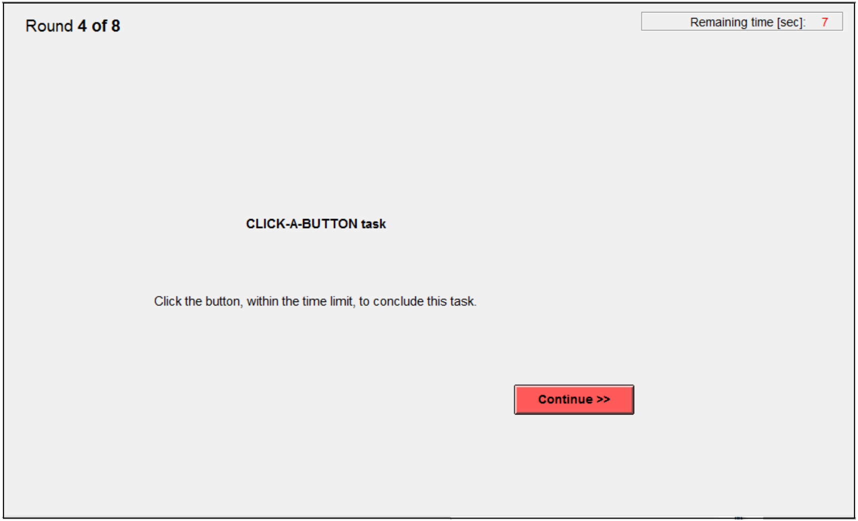
Arithmetic (multiplication) task



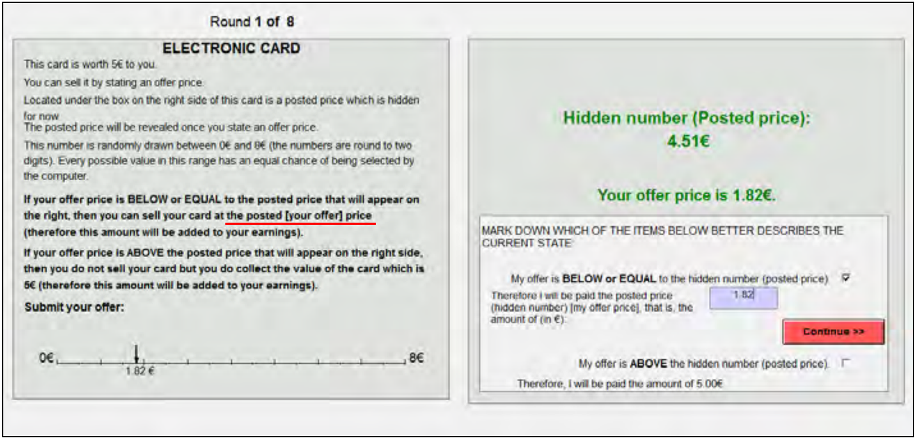
Arithmetic (addition) task



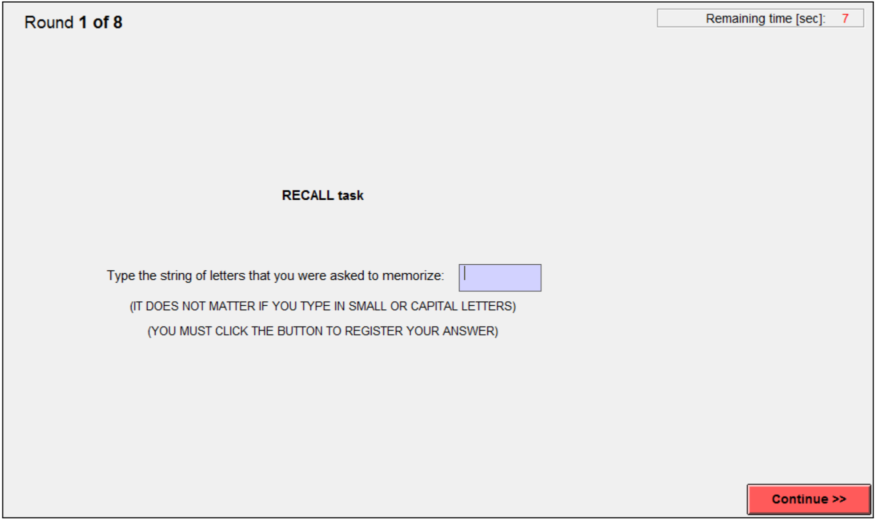
Click-a-button task



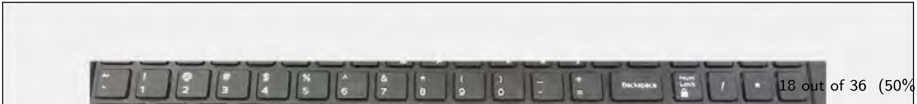
Valuation task



String recall



Training with consonant letter input from the keyboard



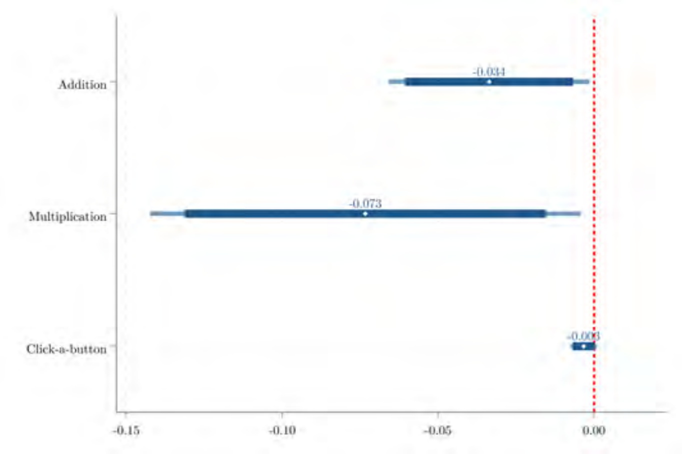
Difficulty of the memorization task

			HCL	LCL
Success rate	Combined over all tasks		36.21%	96.62%
	After...	Multiplication	22.79%	95.49%
		Addition	42.65%	97.74%
		Click-a-button	45.22%	99.25%
		Valuation task	34.19%	93.98%

Manipulation checks

		HCL	LCL	p-value (% test)
	Multiplication	44.85%	51.50%	0.061
Success rate	Addition	84.93%	89.10%	0.005
	Click-a-button	98.53%	99.24%	0.975

Manipulation checks



Valuation task: Optimal offers

Since drawn posted price $p \sim U[0,8]$, then:

Expected payoff in the BDM mechanism

$$E[\pi] = IV \times Prob(b > p) + E(p|b \leq p) \times Prob(b \leq p) =>$$
$$\partial E[\pi]/\partial b = 0 => b^*_{BDM} = IV = 5$$

Expected payoff in the FP auction

$$E[\pi] = IV \times Prob(b > p) + b \times Prob(b \leq p) =>$$
$$\partial E[\pi]/\partial b = 0 => b^*_{FP} = IV/2 + 8/2 = 6.5$$

BDM offers or FPA offers?

Probability of an offer:

$$\text{Prob}(\text{offer} = b_j) = \frac{e^{\lambda E[\pi|b_j]}}{\sum_{k=1}^{n} e^{\lambda E[\pi|b_k]}}$$

If $\lambda = 0$: subjects are insensitive to differences in expected payoffs i.e. they choose all offers with equal probability akin to random choice.
If $\lambda \to \infty$: subjects choose the offer that maximizes their expected payoff with the highest probability. (A higher level of λ indicates a better fit, requiring less noise to characterize subject's choices according to that particular model)

BDM offers or FPA offers?

Expected Payoff under BDM

$$E^{BDM}[\pi] = IV \times \text{Prob}(b > p) + E(p|p > b) \times \text{Prob}(b < p)$$

Expected Payoff under FPA

$$E^{FPA}[\pi] = IV \times \text{Prob}(b > p) + b \times \text{Prob}(b < p)$$

Define the log-likelihood function as:

$$\ln L^m(\lambda; y_i) = \sum_i \ln \frac{y_i e^{\lambda E^m[\pi|b_j]}}{\sum_{k=1}^n e^{\lambda E^m[\pi|b_k]}}$$

where m stands for the optimal model ($m = opt$) or the FPA-GFM model ($m = gfm$) using the corresponding expected payoff expressions and y_i is an indicator that the offer is b_j

BDM offers or FPA offers?: Risk aversion

- With risk averse bidders, optimal offers in an FPA deviate from the risk-neutral offer price of €6.5
- We match our data with data from an incentivized web survey that is being administered annually since 2017 to the student population of the university
- Choices over lotteries: the HL task and a payoff-varying task
- Matched 156 subjects with data from the 2018 wave; 24 subjects with data from the 2017 wave; 23 subjects from the 2019 wave. In total, we matched 75.46% of our sample
- Implicit assumption: risk preferences are not affected by cognitive load

BDM offers or FPA offers?: Risk aversion

Assume a CRRA:

$$EU(b; r, p) = \frac{IV^{1-r}}{1-r} \times \text{Prob}(b > p) + \frac{b^{1-r}}{1-r} \times \text{Prob}(p > b)$$

- Predict r from structural estimations of lottery choices

Then maximize:

$$\ln L^{RA}(\lambda; y_i) = \sum_i \ln \frac{y_i e^{\lambda EU[\pi | b_j]}}{\sum_n^{k=1} e^{\lambda EU[\pi | b_k]}}$$

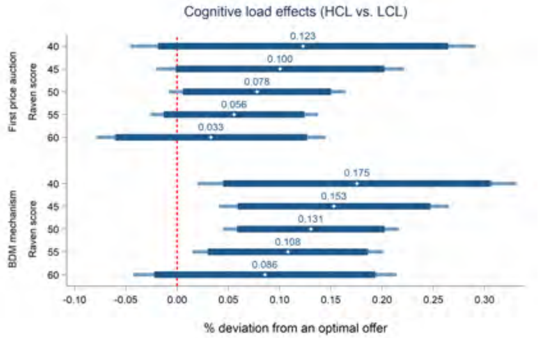
- Or jointly estimate $\ln L(\lambda, r, \mu; y, w) = \ln L^{RA} + \ln L^m$

BDM offers or FPA offers?: Results

		Risk neutrality		Risk aversion	
	Optimal model (1)	FPA-GFM model (2)	Mixture model (3)	FPA-GFM model (4)	Mixture model (5)
λ					
Constant	1.202***	0.285***	1.105*	0.385**	1.170***
	(0.436)	(0.093)	(0.666)	(0.181)	(0.441)
HCL treatment	-1.140**	-0.219*	-1.039	-0.385**	-1.108**
	(0.533)	(0.126)	(0.671)	(0.181)	(0.537)
π_{GFM}					
Constant	-	-	0.084	-	0.088
	-	-	(0.294)	-	(0.256)
HCL treatment	-	-	0.915***	-	-0.088
	-	-	(0.294)	-	(0.256)
N (Subjects)			272 (136)		
Log-likelihood	-1011.551	-1012.372	-1010.748	-1015.772	-1011.465
AIC	2027.103	2028.744	2029.496	2035.545	2030.931
BIC	2034.314	2035.955	2043.919	2042.757	2045.354

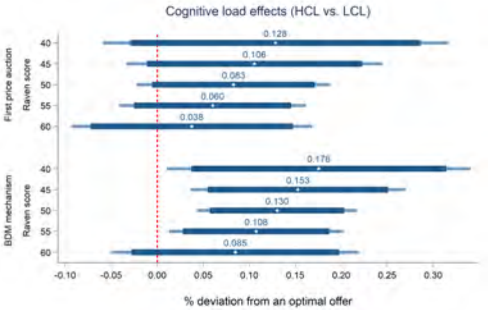
Regressions: Bid deviations

- DV: Absolute deviations from optimal offer in ratio form $\frac{bid - optimal}{optimal}$ to scale differences
- RE regression with clustered SE
- IVs: Period, gender, age, income and Cognitive load##BDM, Cognitive load##Raven score, BDM##Raven score



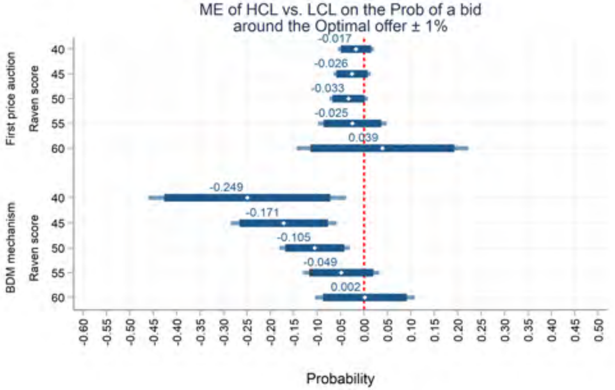
Regressions: Bid deviations

- Risk averse bids: from $EU(b; r, \bar{p}) = \frac{IV^{1-r}}{1-r}\frac{b}{\bar{p}} + \frac{b^{1-r}}{1-r}(1 - \frac{b}{\bar{p}})$
- Given an induced value of $IV = 5$, a maximum randomly drawn price of $\bar{p} = 8$ and setting $\frac{\partial EU}{\partial b} = 0$ gives:
  $5^{1-r} + (1-r)b^{-r}(8-b) - b^{1-r} = 0$
- Setting individual predictions of r, gives an individual specific optimal bid $b \neq 6.5$



Regressions: Optimal offers

- DV: Dummy, 1=S made an offer around X% of the optimal offer price
- RE Logit with clustered SE
- IVs: Period, gender, age, income and Cognitive load##BDM, Cognitive load##Raven score, BDM##Raven score

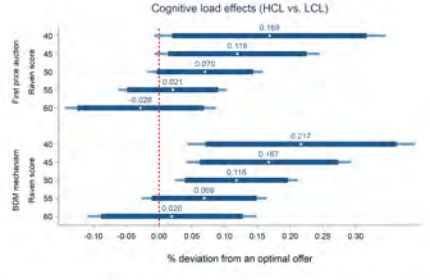


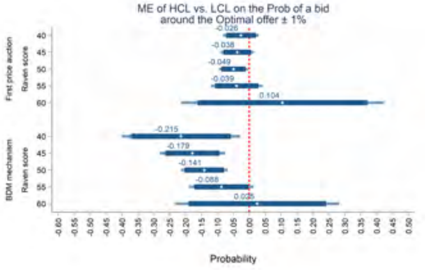
Robustness checks: attention to instructions

Question/Scale		LCL FPA	LCL BDM	LCL *FPA+BDM*	HCL FPA	HCL BDM	HCL *FPA+BDM*
Carefully read instructions for the BDM (FPA) task	1 = Not careful at all	1	0	*1*	0	0	*0*
	2	1	0	*1*	1	1	*2*
	3	5	3	*8*	14	17	*31*
	4	23	33	*56*	27	26	*53*
	5 = Very careful	37	30	*67*	24	26	*50*
How well did subject comprehend instructions in the BDM (FPA) task	1= Not well at all	2	0	*2*	1	1	*2*
	2	0	0	*0*	1	0	*1*
	3	5	6	*11*	6	12	*18*
	4	27	39	*66*	38	33	*71*
	5 = Very well	33	21	*54*	20	24	*44*
During the experiment, subject was ...							
1= ...focused on reading instructions for the BDM (FPA) task		4	3	*7*	12	14	*26*
2= ...focused on memorizing the string		1	0	*1*	6	7	*13*
3= ...paid attention in reading instructions for the BDM (FPA) task as well as memorizing the string		62	63	*125*	48	49	*97*

Robustness checks: attention to instructions

- Rerun the analysis with 221 subjects: those that stated to carefully read/comprehend the instructions at a moderate level or better AND those that stated they paid attention in both reading the instructions and memorizing the letter/string



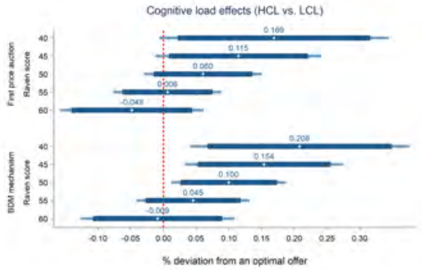


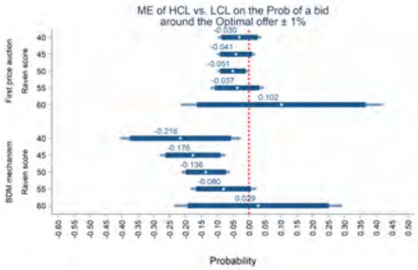
Robustness checks: payoff understanding

Subject perceives that ...	Treatments		Bid < Posted price N	Bid < Posted price Perceived Payoff	Bid < Posted price Actual Payoff	Bid > Posted price N	Bid > Posted price Actual Payoff
Bid < Posted price	HCL	BDM	55	5.53	5.45	*12*	*4.58*
		FPA	49	3.64	3.47	*4*	*3.06*
	LCL	BDM	55	6.08	6.23	*4*	*6.66*
		FPA	48	4.06	3.88	*2*	*1.56*
Bid > Posted price	HCL	BDM	*0*	-	-	73	5.00
		FPA	*3*	*4.27*	*5.00*	76	5.00
	LCL	BDM	*3*	*3.61*	*5.00*	70	5.00
		FPA	*1*	*8.00*	*5.00*	83	5.00

Robustness checks: payoff understanding

- Rerun the analysis with 208 subjects: those that stated to carefully read/comprehend the instructions at a moderate level or better AND those that stated they paid attention in both reading the instructions and memorizing the letter/string AND good understanding of the payoff structure





Conclusions

- Impaired subjects' cognitive ability by taxing their working memory capacity
- Detrimental effects on math tasks (multiplication, addition); not on simple click-a-button
- The BDM is not a accurate preference revelation mechanism; however, offers are not consistent with a FPA-GFM model
- HCL in the BDM makes decision process equivalent to random choice
- HCL does not significantly affect bidding in the FPA
- HCL does affect the BDM mechanism for subjects of low cognitive ability; but not for subjects of high cognitive ability

Finale!

Thank you for your attention!

Additional slides follow:

Was sample size large enough?

- What is the effect size that our sample size was powerful enough to detect?
- $n = \frac{2(z_{1-\alpha/2}+z_{1-\beta})^2(1+(M-1)\rho)}{M(\frac{\mu_0-\mu_1}{\sigma})^2}$ where $\alpha = 5\%$ (Type I error) and $\beta = 20\%$ (Type II error) (Kupper & Hafner, 1989; Diggle et al., 2002)
- μ_0 and μ_1 are the group means, with common variance σ^2; M is the number of repeated measurements
- Feed the formula with plausible values for $d = \mu_0 - \mu_1$ and σ^2 from past studies (Table 1 in Bull et al. 2018)

		σ =0.9	σ =0.95	σ =1	σ =1.05	σ =1.10	σ =1.15
	ρ =0	25	28	31	35	38	42
d =0.5	ρ =0.5	38	43	47	52	57	62
	ρ =0.8	46	51	57	62	68	75
	ρ =0	21	23	26	29	31	34
d =0.55	ρ =0.5	32	35	39	43	47	51
	ρ =0.8	38	42	47	51	57	62
	ρ =0	18	20	22	24	26	29
d =0.60	ρ =0.5	26	30	33	36	40	43
	ρ =0.8	32	35	39	43	47	52