Instinctive and Cognitive Reasoning : Response Times Study

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This work could not be done without the collaboration with Eli Zvuluny with whom I built the site http://gametheory.tau.ac.il . This site was the platform on which we conducted our experiments.

I would like to thank Michael Ornstein who helped me in various stages of the project, preparing the graphs and giving good advise. I would like also to thank Gur Huberman: the idea to record response times came to our mind during our work on the unfinished "two consents" project .

Abstract

The hypothesis of this research project is that actions which are instinctive and derived from emotional responses should require less response time than actions which require the use of cognitive power. Thousands of data observations were collected from students and lecture audiences through the site gametheory.tau.ac.il. The subjects were asked to respond to virtual decision and game situations. In certain examples (such as the beauty contest game), where there is a clear distinction between the instinctive and cognitive actions, the data support the hypothesis. In other examples (such as the dictator game), the data is helpful in identifying the instinctive action.

Key Words: Response Times, Instinctive and Congintive, Reasoning, Experimental Game Theory

1. **Introduction**

There is a growing interest in economics in the bounds on the rationality of economic agents. More and more economists are abandoning the "economic man" paradigm and are using models that reflect what they consider to be more realistic descriptions of the way in which human beings make decisions. One can identify three approaches in the literature to "opening the black box" of decision making:

Bounded Rationality

We first assemble casual observations (mainly from our own decision making processes) about the way in which people deliberate. The observations lead us to construct abstract models which are intended to increase our understanding of the effect of certain decision procedural elements on the outcome of an economic interaction (see Rubinstein (1998)) . Thus, for example, we investigated repeated games in which players consider not only their standard game payoff but also the complexity of their strategies. The inclusion of complexity considerations in these models is based on intuitions about the meaning of complexity in long term strategic situations. However, our choice of the actual complexity measures is not linked to any empirical findings.

Behavioral Economics

Daniel Kahneman and Amos Tversky launched a project which not only refuted the standard use of the economic man paradigm but also identified psychological elements which are systematically used by decision makers. Their findings demonstrated the involvement of emotions and procedural elements which were missing from the standard application of rationality in economics . The findings of the "Kahanman and Tversky" school, as well as the feeling that traditional models had been exhausted, led in the nineties to the establishment of the field called "Behavioral Economics". In this research the economic agent is rational in the economic sense of maximizing a well defined target function. However, researchers in the field did not feel obliged to identify rationality with maximizing only "materialistic consequences". Standard behavioral economics does not relate to procedural elements of decision making. (For an exception that I am of course aware of, see Rubinstein (1988) in which, following Tversky's work on similarity, a procedure for constructing similarity-based preferences between vectors is analyzed.) Constructing the interaction between agents who do not behave as utility maximizers requires the invention of new notions of equilibrium (see, for example, Osborne and Rubinstein (1998)).

Brain Studies

Following the advances in brain research and especially the increased accessibility of machines using functional magnetic resonance imaging (fMRI), some researchers have started monitoring brain activity during decision making (see, for example, Sanfey, Rilling, Aronson, Nystrom and Cohen (2003)). The idea is to have subjects make a decision or play a game inside the machine and to look for correlations between the decision they make and the activities in certain brain centers which are assumed to conduct certain functions (such as expressing emotions or executing cognitive operations). This is an expensive and speculative type of research. The technical constraints result in small samples, the data is very noisy and the interpretation of the findings is far from indisputable.

Whereas brain studies try to make inferences from differences in brain activity about what is going on in our "black box", one could think of more obvious physical hints about the way in which people reason. Previous research in game theory and decision making used monitored information about the way in which subjects respond to game situations in order to draw conclusions about their deliberation algorithm. In particular, see Camerer, Johnson, Rymon and Sen (1993) who used the order of mouse clicks to demonstrate that people analyze an extensive game forwards and not backwards as implicitly assumed by standard game theoretical solution concepts. The basic idea of this research project is to elicit hints about the deliberation process of decision makers from their response time. The hypothesis is that actions which are instinctive and derived from emotional responses should require less response time than actions which require the use of cognitive power. The time it takes for agent to reach a decision should be correlated with the cognitive component of the decision.

Very few experimental papers in game theory have reported time responses (for one exception, see Wilcox (1993)). The problem with measuring response time is the huge variance in its values. Most experiments in economics and game theory are done with small samples (for an exception, see Guth, Schmidt and Sutter (2003)). Measuring the time of response on the standard-sized samples used in economics would be meaningless. Finding a large population requires a special opportunity.

The opportunity to conduct a very large scale experiment which would provide a large number of responses presented itself with the construction of the site http://gametheory.tau.ac.il which I built together with Eli Zvuluny. The purpose of the site was "to provide the teacher of a basic course in Game Theory with a free user-friendly didactic tool for conducting web-based thought experiments." Teachers are advised to assign their students "pre-class" problems which are virtual games (see Rubinstein (1999) for the teaching method behind the site). The site was launched in January 2001. During its three years of operation, 50 teachers from 23 countries have actively used it. Most of the users are from departments of economics although some are from computer sciences, political sciences, business or law. More than 2500 students have participated in at least one experiment. Almost all the students responded to questions in English but a few responded to questions in Portuguese, Russian and Spanish.

A few months after launch, the site was modified to record the subject's response time (RT). Subjects were not informed we were recording their RT which was defined as the number of seconds between the moment that our server receives the request for a problem until the moment that an answer is returned to the server.

A further opportunity to collect data on a large scale arose as a result of a public lecture which I have delivered nine times since May 2002. In the lecture, entitled "John Nash, Beautiful Mind and Game Theory", I presented my personal encounter with John Nash, introduced the basic ideas of Game Theory from a critical point of view and spoke a little bit about the book and the movie. The audience (mostly students and faculty) were approached prior to the lecture and asked to respond via gametheory.tau.ac.il to several questions. In seven of the universities - Technion (Israel), Tilburg University (Holland), the London School of Economics (UK), University of British Columbia and York (Canada), Georgetown University (USA) and Sabanci (Turkey) - I measured response time. About 2500 subjects responded to a small number of questions, thus creating a huge database. This second collection of data had advantages over the first. For one thing, they were taken from a small number of universities which reduced noise. Thus, whenever I have data from the Nash lectures I will present only those results (though in those cases results from the university classes are not significantly different). In one case, in which a problem was presented to only one lecture audience, I present the combined data of the two sampling methods.

In what follows, I present some of the more interesting results I obtained using the above method. I will proceed with the hypothesis in mind that responses which require more cognitive activity take more RT than responses which reflect instinctive response.

2. Results: Matrix Games

We start with two examples of matrix games which were presented to students in classes.

Example 1: A Zero Sum Game (#15):

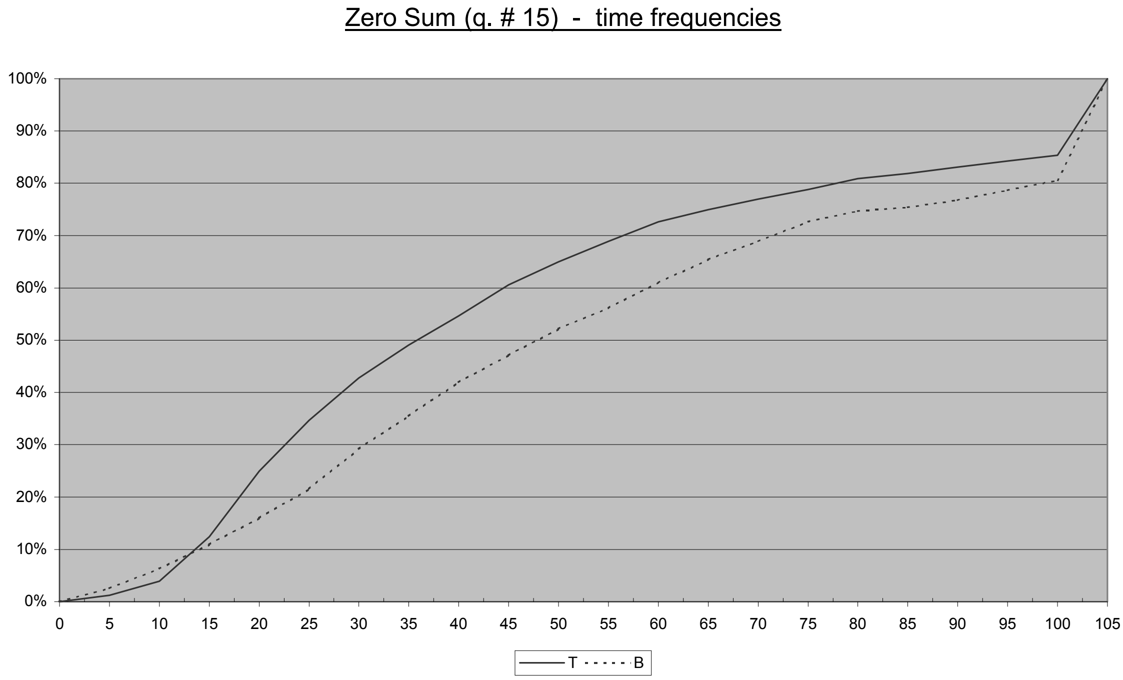
	L	R
T	$2,-2$	$0,0$
B	$0,0$	$1,-1$

Subjects were asked to imagine they play the above matrix game in the role of player 1 against an anonymous player. The question did not specify the meaning of the numbers. If the subjects interpret them as vNM utilities than the unique mixed strategy Nash equilibrium predicts that the action *T* will be taken with probability 1/3. But in any case that subject preferred a an higher payoff Nash equilibrium predicts that the proportion of subjects playing *T* will be less than those who play *B*.

A large number, 1257, of students in 27 courses responded to the question, 2/3 of them chose the action *T*, the one which Nash equlbrium predicts to be less frequent.

I think that playing *T* is the instinctive action in this game as *T* since the number 2 triggers the instinct to go after the a large payoff. Playing *B*, the one predicted to be more common in Nash equilibrium, requires more cognitive thinking (like, speculating that player 2 will not likely to play *L*, to avoid the big loss, and thus I better play *B*). Our hypothesis predicts that the MRT of *T* should be lower than of *B*.

This is indeed the case. The MRT (median response time) of the subjects choosing *B* was 48*s*, 30% higher than the MRT of *T* which was only 37*s*. The graphs of the accumulative distributions of RT among the chooser of *T* is clearly (first order) stochastic dominated by the corresponding graph for *B*. Our hypothesis gets a clear support.



—Figure 1——

Example 2: Successive Elimination of Strategies (#4 in the site)

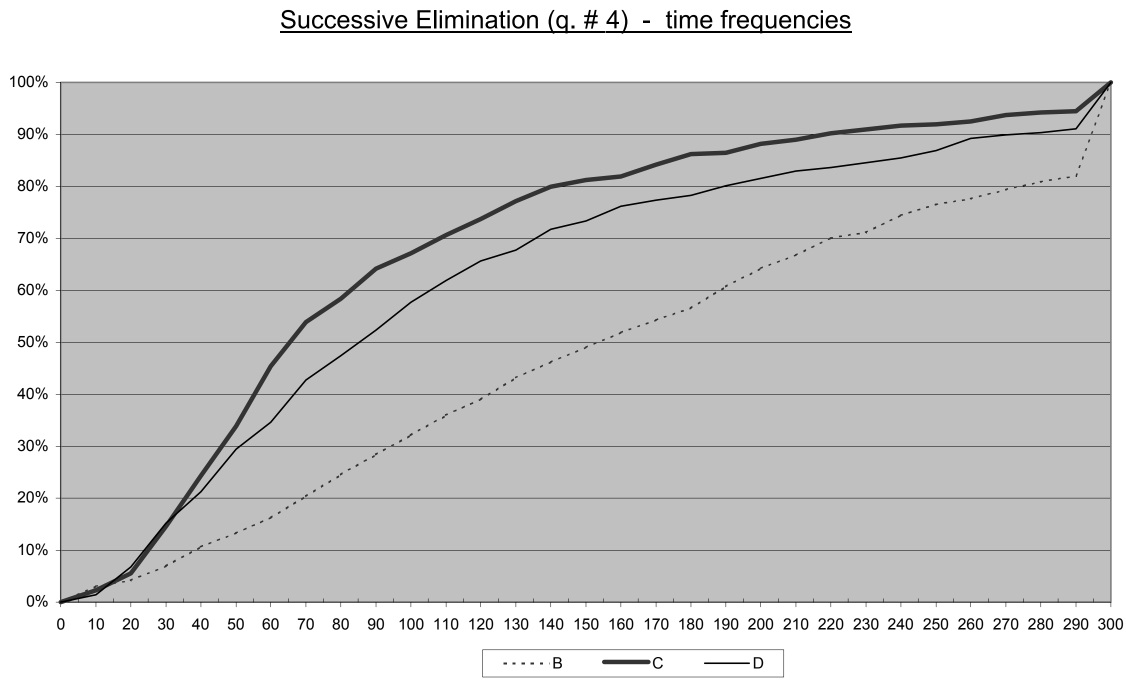
1320 subjects in 34 courses were asked to imagine playing the following two-player game in the role of the row player:

	A	*B*	*C*	*D*
A	5, 2	2, 6	1, 4	0, 4
B	0, 0	3, 2	2, 1	1, 1
C	7, 0	2, 2	1, 5	5, 1
D	9, 5	1, 3	0, 2	4, 8

The instinctive responses here are *C* and *D*; the action *D* because of the "9" the highest payoff in the matrix, and the action *C* since the average payoff in its row is the highest. However, successive elimination of strongly dominated strategies leads to *B*. The elimination order is 2*A*, 1*A* + *D*, 2*D*, 1*C*, 1*C*, 2*C*. Thus, the action *B* to be the one which require more cognitive reasoning.

Total	100%	1320	96
Action	%	#	*median*
A	2%	32	74*s*
B	35%	461	153*s*
C	30%	399	65*s*
D	32%	428	86*s*

The data supports the hypothesis. Let us ignore the action *A* which was hardly chosen (by 31 subjects). Each of the other three choices was selected by a nice size population of 400 subjects or more. As is seen from the table and the graph the action *B* required about double the time it took to those who chose the instinctive actions *C* and *D*.



—Figure 2——

Note that *C* was quicker to be chosen than *D*. This casts doubt on an hypothesis that subjects follow a part of the successive elimination process as *D* is eliminated before *C*.

3. Results: The traveler's dilemma and the Beauty Contest

Let us move to results of two problems which are often used to demonstrate the tension between the clear cut game theoretic analysis which depends on serial inductive thinking and actual behavior.

Example 3. The Traveler's Dilemma (#53)

Subjects in the Nash lectures were asked to respond to the following problem:

Imagine you are one of the players in the following two-player game:

*- Each of the players chooses an amount between $*180 *and $*300*.*

- Both players are paid the lower of the two chosen amounts.

- Five dollars are transferred from the player who chose the larger amount to the player who chose the smaller one.

- In the case that both players choose the same amount, they both receive that amount and no transfer is made

What is your choice?

Assuming that the players care only about their final dollar payoff the only equlibirum strategy of this game is the choice of 180. The response 300 is clealry the instinctive action and the answers 181-294 seem to follow an algorithm like "pick a number" . The most cognitive responses must be 295 – 9 using strategic reasoning.

The following table and Figure 4 summarize the results among 2985 subjects:

	Nash Lectures	MRT
n	2985	77
180	13%	87s
181-294	14%	70s
295-299	17%	96s
300	55%	72s

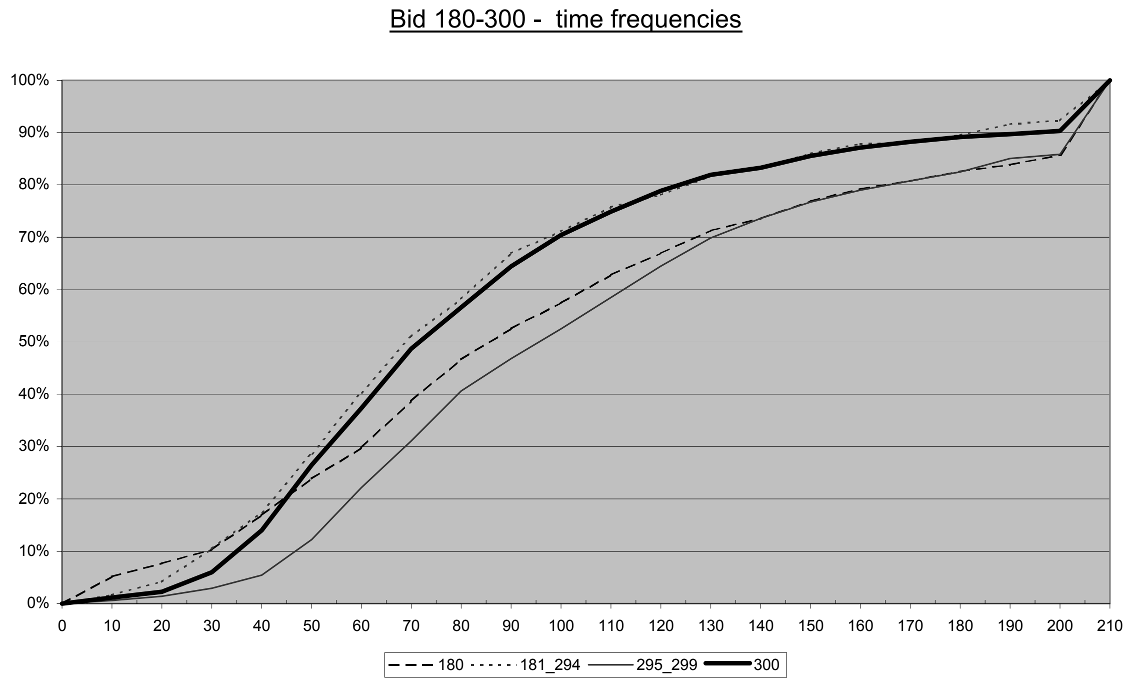


Figure 3

The distribution of answers is not substantially different from Goheree and Holt (2001) results with real payoffs and a sample of 50 (8%, 18%, 24% and 50% accordingly). The RT results confirm the hypothesis: the MRT of the more cognitive responses and especially 295-299 is significantly higher than the instinctive responses.

Example 4: Guess 2/3 of the Average (#1)

The Beauty contest game is another game where the depth of reasoning was speculated to be the source of different of behaviors. Subjects got the following instructions:

"*Each of you (the students in this course) have to choose an integer between* 0 *and* 100 *in order to guess"*2/3 *of the average of the responses given by all students in the course".*

Each student who guesses 2/3 *of the average of all responses rounded up to the nearest integer, will receive a prize to be announced by your teacher (or alternatively will have the satisfaction of being right!).*

What is your guess?"

Recall that successive elimination of dominated strategies eliminate all actions besides 0 or 1; combinations of those two actions are consist of Nash equilibria of the game. The game was heavily experimented, see for example Nagel (1995). Here, 1257 subjects in 40 courses had an average guess of 36.9, precisely the number Nagel got.

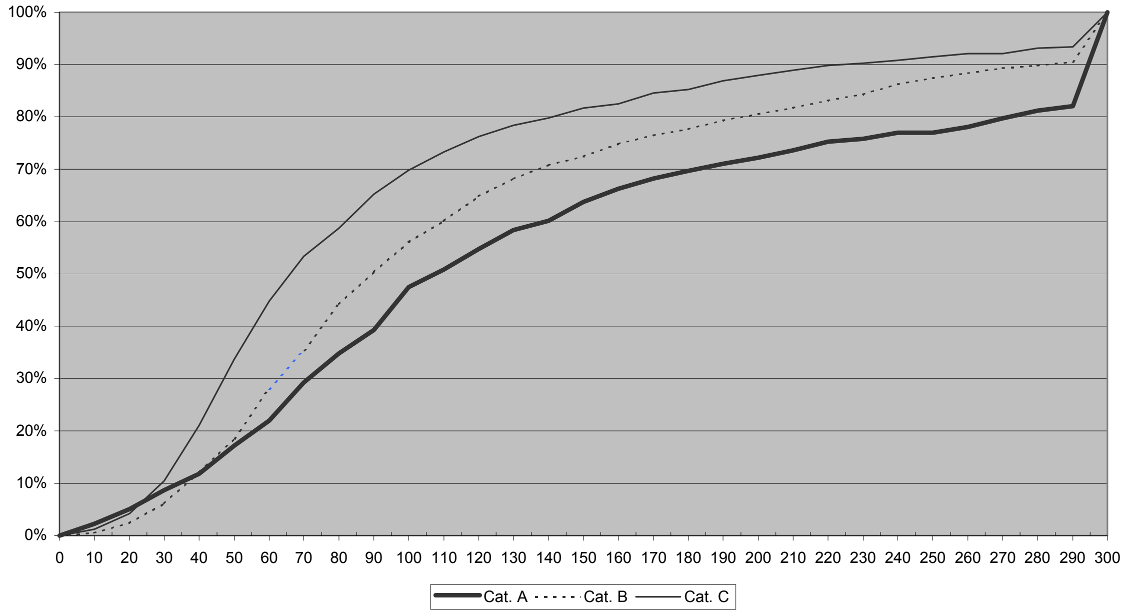
Responses of 50 and more (class C) seem to indicate misunderstanding of the game. The responses $33-34, 22$, $14-15$, seem to go through the process of reasoning “the average will be 50 so that I choose a number around $2/3 * 50 = 33.3$ ”, or iteration of this argument, once or twice. Category A includes $33, 34, 22, 14, 15$ and also the Nash equilibirum actions 0 and 1.

The rest are classified in B seem to express arbiterness and “a best response against a wild guess”.

	#	MRT	0 – 1	2 – 13	14 – 15	16 – 21	22	23 – 32	33 – 34	35 – 49	50	51 –
Classes	1257	85*s*	11%	8%	2%	6%	4%	9%	11%	10%	17%	21%
MRT A	28%	105*s*	98*s*		100*s*		141*s*		103*s*			
MRT B	33%	90*s*		83*s*		80*s*		90*s*		94*s*		
MRT C	38%	66*s*									67*s*	66*s*

The results are sumamrized in the table and Figure 4. Clealry the people who choose an action in class A thought more than the other and those subjects who made choices in C subjects tend to think much less.

Guess 2/3 of the average (q. # 1) - time frequencies



—Figure 4—

The results cast doubt on the classification used by Nagel and other: Nagel classifies in one group the whole range 20 – 25. However, by my data, the MRT among the 4% who chose "22" was 141*s* while the MRT among the 8% who chose 20,21,23,24or 25 was only 80s! This must indicate that there is very little in common between the choice of 22 and the rest of Nagel's class of "Step 2".

4. The Dictator and Ultimatum Games

Following the work of Werner Guth, much experimental work in game theory has been about the ultimatum game: Two individuals can divide between them, for example, $100. One player has to propose how to divide the sum. The second can say "yes" or "no." If he agreed the $100 are split according to the proposal and if not both get nothing. It is customary to assume that each player is only interested in attaining as much money as possible. Applying the Subgame Perfect Equilibrium concept we usually say that "game theory predicts" that the proposer will offer only $1 or $0 to the responder who will accept the offer.

Of course, this description is not realistic: In life, the proposer often cares about the amount of money he gives to the other player (feeling bad for utilizing his preferred status) and is afraid that the responder might be insulated by an offer which is too low, and feel he would prefer to get nothing than agreeing to the "insulting low offer".

The "dictator game" is one way proposed in the literature to distinguish between the consideration of the proposer preferring an equal division and the consideration of fear from responder's revenge after an unfair proposal. In the "dictator game" one player has the exclusive right to determine the division of the $100 without the need of the other player's consent. The following problem was offered in the site for classes:

Example 5: The Dictator game (#21)

Imagine that your teacher will randomly select two students in the class. One of them will be assigned to play the role of player 1*, while the other will be assigned to play the role of player* 2*.* $20 *will be divided between the two according to player* 1*'s choice in the following statement:*

I will divide the $20 *as follows:N Dollars for me, the rest for the other student.*

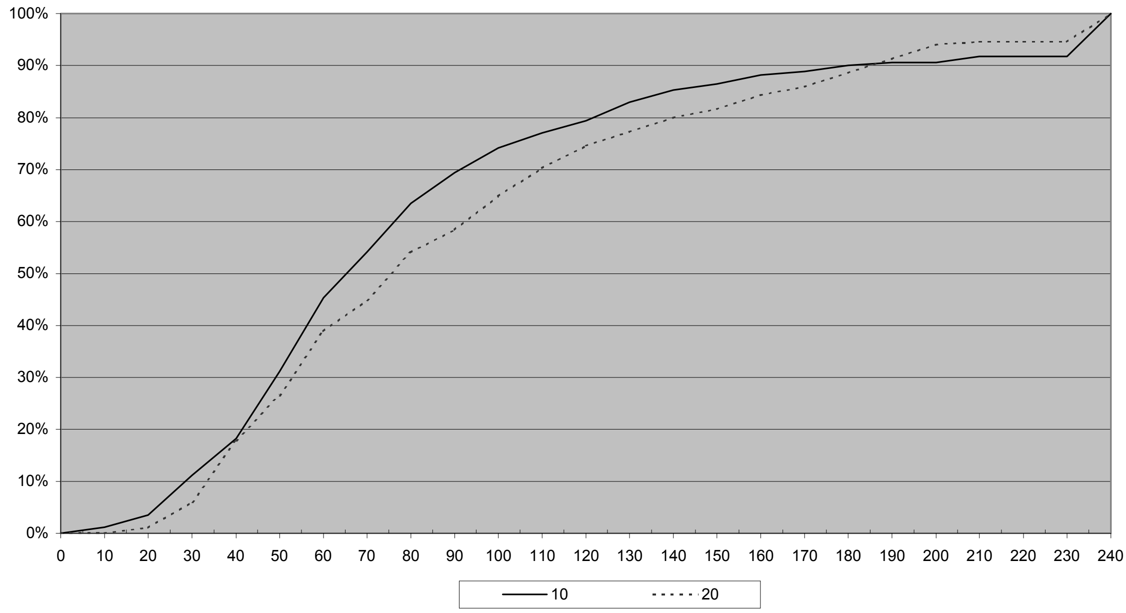
The prize will be given anonymously to the two students.

What is your choice of N?

507 subjects in 15 classes have responded to this question. Two prominent choices, "the equal split" and "take it all" were chosen by 69% of the subjects: 34% of the subjects chose the equal split and 35% chose to take all the $20. (Forsythe, Horowitz, Savin, and Sefton (1994) with real money also found that only 35% chose to grab the whole sum.)

I found it interesting to compare the RT of the two main modes of response. Having one of the options a significant lower RT might mean that this one is the more instinctive response. Indeed the MRT of the equal split was 66*s* much less than the MRT of "take it all" which is 75*s*. The RT distributions appear in Figure 5 and give us reason to conjecture that the fair division is the more instinctive action in this case.

Dictator - Chosing to take (q. # 21) - time frequencies



—figure 5—–

Let us move to the ultimatum game itself for which I had a huge database gathered along the Nash lectures. (Once again, I don't find significant difference between the results for the Nash lectures and regular classes).

Example 6: The Ultimatum game (#23)

*Imagine that you and a person you do not know are to share $*100.

*You must make an offer as to how to split the $*100 *between the two of you and he must either accept or reject your offer. In the case that he rejects the offer, neither of you will get anything.*

What is your offer ?

*I offer the following amount to the other person (if he agrees I will get the rest):*____

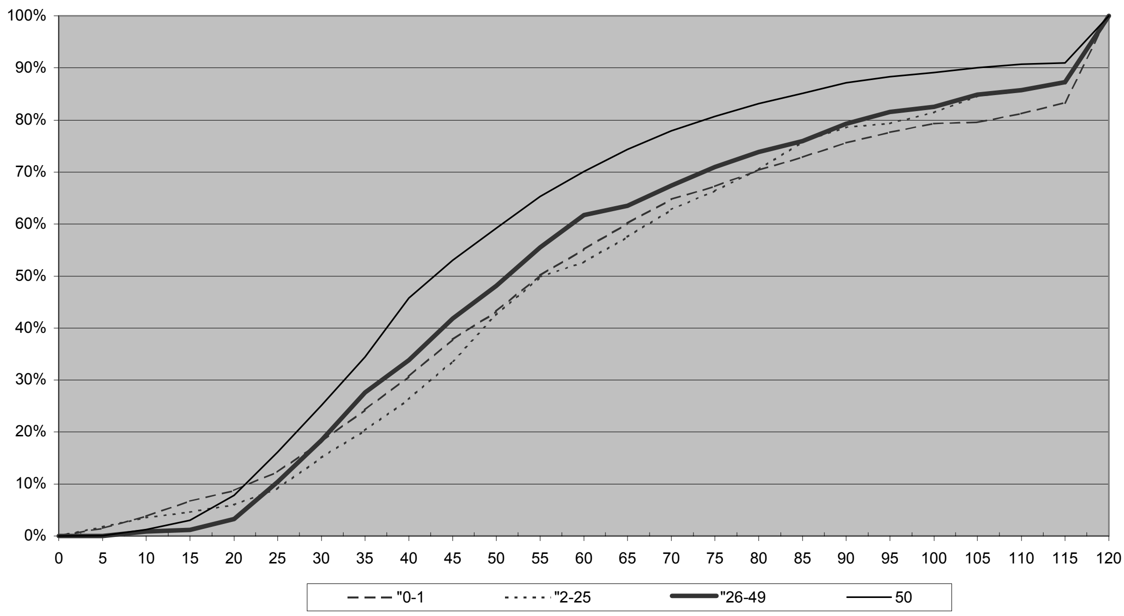
The results in 9 universities in 6 countries, Israel, Canada, USA, Turkey, Holland and UK were quite similar and demonstrated some systematic gender differences (on average females offered more). I recorded the RT of 3202 subjects and the results are summarized in the table:

Answer	Nash Lectures	MRT
	3202	49
0 – 1	15%	55
2 – 25	9%	56
26 – 49	11%	52
50	46%	43
51 – 60	11%	55
61 – 100	8%	46

The MRT of those who offered less than $50 was 25% higher than of those who offered equal division. This, supports our hypothesis that the equal division is the instinctive action.

A substantial group emerges in all universities: those who offered the other player more than 50%. The low MRT supports the conjecture that many of those who offered 61 and more did not understand the question well. However, the MRT of those in the range 51-60 was not different from those who offered 40-49 and thus might be intentional.

Ultimatum(Offerer) (q. # 23) - time frequencies



—Figure 6—

A Nash lecture invitee were asked also to imagine he is a responder in the ultimatum game who has been offered $10 out of the $100.

Problem 7: The Ultimatum Game: A Responder (#25)

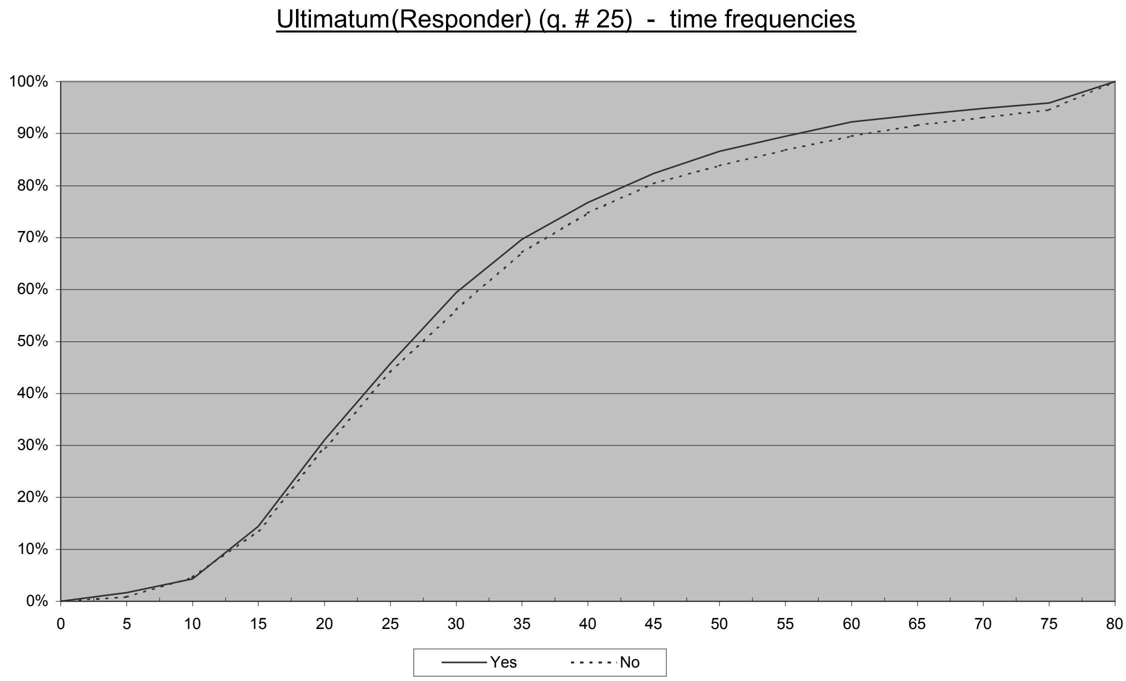
*You and someone you do not know are to share $*100*. He makes you an offer and you can either accept it or reject it.*

*If you reject it, neither of you will get anything. He offers you $*10 *(if you accept, he will get $*90*).*

Do you accept the offer? Yes/No

Note, that in the Nash lecture questionnaires Problem 6 was always the first while Problem 7 was always the last. The RT of 2620 invitees in Technion, Tilburg, LSE, Georgetown, UBC and Sananci universities, were recorded. A surprisingly high proportion of subjects, 63% , "accepted" the offer. Is there a difference in the RT between those who accept and those who reject the $10 ? (By the way, 95% of those who offered 0-10 in the previous question has accepted the $10 in contrast to the only 53% of those who offered an equal split of the sum and accepted the offer of $10)

Remarkably, not only the median of the two groups was identical 27-28s but as Figure 7 shows the RT distributions of those who accept or reject does not show any difference.



—Figure 7—

In the lecture in York a similar question with $5 replacing $10 was posted and the number of responders was 274. The acceptance rate dropped to 52% but again there was no significant difference between the RT of those who accepted (MRT of 34s) and rejected the offer (MRT of 32s).

This result seems to be with some conflict with the results reported by the fMRI experiment. Sanfey, Riling, Aronson, Nysstrom and Cohen (2003) attributed acceptance of the low offer to the cognitive side and rejection to the emotional emotional part of the brain. But, the identity between the RT distributions of those who accepted and those who rejected does not seem to support this claim.

5. A decision Problem

Up to now, all problems were game theoretic. The last example is a variant of the Allais Paradox taken from Tversky and Kahneman (1979):

Problem 8: The Allais Paradox (#39 and #40)

Participants in a Nash lecture in York University were asked to respond to the following two questions, A first and B second with several questions in between. A similar number of students responded to those questions in classes (and teachers were advised to offer the questions in this order as well). In order to obtain a large data base, and given the similarly of results I present the results of the Nash lecture and the classes together.

A

Imagine you have to choose one of the following two lotteries :

*Lottery A yields $*4000 *with probability* 0.2 *and $*0 *with probability* 0.8.

*Lottery B yields $*3000 *with probability* 0.25 *and $*0 *with probability* 0.75.

What lottery would you choose ?

B

Imagine you have to choose one of the following two lotteries :

*Lottery C yields $*4000 *with probability* 0.8 *and $*0 *with probability* 0.2.

Lottery D $ 3000 *with probability* 1.

What lottery would you choose ?

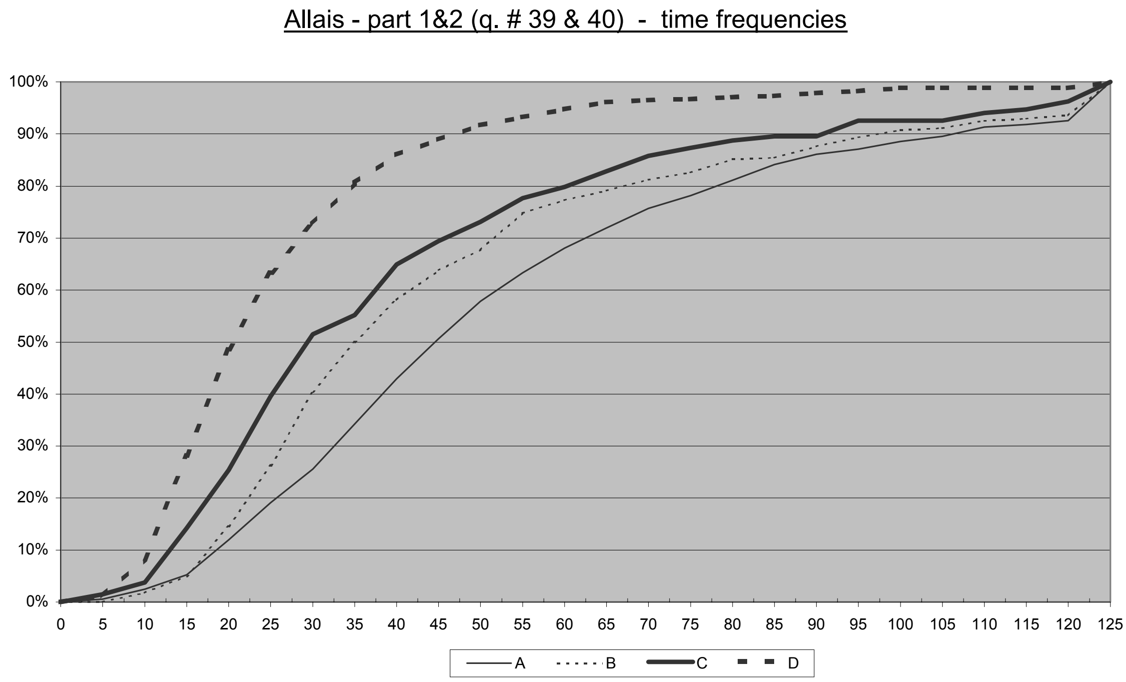
The results in the virtual experiment and in Kahneman and Tversky (1979) are very similar. The following table and graph 8 summarize the results including the MRTs:

	Kahneman + Tversky	*York + classes*	*MRT*
A	95	685	42*s*
$0.2[4000] + 0.8[0]$	65%	59%	45*s*
$0.25[3000] + 0.75[0]$	35%	41%	36*s*
B	95	650	23*s*
$0.8[4000] + 0.2[0]$	20%	21%	30*s*
$[3000]$	80%	79%	21*s*

In the problem B the sure prize [3000] is clearly the instinctive response; the choice of the risky lottery $0.8[4000] + 0.8[0]$ requires calculation and deliberation.

Regarding problem A, the choice of $0.2[4000] + 0.8[0]$ over $0.25[3000] + 0.75[0]$ is explained either by the comparison of the expectations or by the procedure (described in

Rubinstein (1988)) where the decision maker finds the probabilities similar and makes the choice by the decisive prize difference.   In both case the choice requires a cognitive action something which in line with the higher RT.



—Figure 8—

6. Conclusion

I am aware of potential criticisms on the approach suggested in this paper: Fir example: The data is blurred by the behavior of subjects who“pick” without serious deliberation. The data is noisy due to differences in server speed. Subjects differ in their speed of reading. Subjects differ in their speed of thinking. Nevertheless, I think that due to the huge sample we do get a clear and stable picture.

A standard criticism on survey experiments is that once no monetary rewards are offered the behavior is less significant. I beg to differ. In my experience there is only non-qualitative difference between survey results and results in experiments where money is paid (See Camerer and Hogarth (1999)).

Overall, I believe that the methodology used in this paper, is a cheap and illuminating tool for getting hints about the process of reasoning leading to classical economic decision problems. Overall, I think that for those cases that it was quite clear what is the more cognitive action (like Problem 2) the results confirm the hypothesis that responses which are naturally classified as cognitive take more time than those which are instinctive. In cases (like the Dictator game) where it was less clear what is the instinctive action the results help us to identify what is the instinctive action. In any case, the results seem to be more significant and less speculative than the results obtained recently by the fMRI fans.

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