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## **GARP FOR KIDS: ON THE DEVELOPMENT OF RATIONAL CHOICE BEHAVIOR.**

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Do children choose rationally? This question matters for several reasons. If children are incapable of choosing rationally, then there is little point in attempting to use standard economic models to describe their behavior. For example, models of family bargaining behavior assume that family members each act rationally to maximize a utility function. On a more applied level, families and society engage in a wide variety of paternalistic policies towards children. These policies use various mechanisms to encourage certain choices and discourage or prohibit others. The issue of rational choice by children is important both for justifying this paternalism and for determining the effectiveness of incentive based mechanisms for enforcing it. It is also difficult to justify using data on children's choices to draw inferences about their preferences, or to accurately predict their future behavior, if the choices are not rational.

In addition to these reasons, which apply to children as children, there is the fact that children grow into adults. An understanding of the development of rational choice behavior over the lifespan may ultimately tell us something about rational choice by adults. Is the ability to choose rationally something that is universally present at very young ages, or does it only appear at adulthood, or even later? Is rational choice the rule, or the exception, among children? If rational choice is not the rule, then do children who reason better also choose more rationally?

In this paper we report on the results of an experiment that tests whether children make rational choices about consumption goods. We studied 7 and 11-year-old children and, for comparison, college undergraduates. The experiment tests variations on what might be seen as the most basic requirement for rationality, namely that choices must obey transitivity. If a person picks A when given a choice between A and B, and B when given a choice between B and C, then

rationality requires that he must pick A when given a choice between A and C. We also examine how rationality, as measured by several different tests of transitivity and by a simple measure of the size of the violations, changes with age and mathematical ability.

The next section explains the relevant aspects of the theory that relates choice behavior and utility maximization in more detail. This is followed by a discussion of some previous experiments on adults and animals, and then by sections discussing our protocol and results, and then a conclusion.

## I. Theory

Revealed preference theory began with Paul A. Samuelson (1938), who showed that it was possible to think about rational choice purely in terms of observable data, without recourse to unobservable constructs like utility. Hendrik S. Houthakker (1950), and Sidney N. Afriat (1967) gave necessary and sufficient conditions for choice data to be consistent with utility maximization. Hal R. Varian (1982) refined the main theorem in Afriat's paper, and proved that satisfying the Generalized Axiom of Revealed Preference is a necessary and sufficient condition for choice data to be consistent with the maximization of a continuous, concave, locally nonsatiated, and weakly monotonic utility function. This means that if choices satisfy GARP we lose nothing by using standard economic models to analyze behavior. This leads naturally to the idea of testing the otherwise unobservable hypothesis of utility maximization, by checking to see if some set of observed choice data is consistent with GARP.<sup>1</sup> In this section of the paper we explain what this test entails.

Prior theoretical work assumes that choices are made from continuous budget sets, defined by prices and incomes. Since many of our participants have trouble doing the math needed to stay within a budget constraint, in our experiment we had them make choices from finite sets of allowable bundles. This means we need to restate GARP in terms of choices, as follows. First, we say that a person directly reveals that they prefer bundle  $x^i$  to bundle  $x$  when they choose  $x^i$  over  $x$  or over a bundle with at least as much of every good as in  $x$ , and more of at least one. We say that a person indirectly reveals that they prefer  $x^i$  to bundle  $x$  when some sequence of directly preferred

relations between bundles connects  $x^i$  to  $x$ . GARP then requires that if a person directly or indirectly reveals that they prefer  $x^i$  to  $x$ , they cannot choose bundle  $x^i$  when some alternative  $x^j$  with at least as much of every good as in  $x$ , and more of at least one, is available. We can then state a new version of Afriat's theorem: If choices satisfy this version of GARP, they are consistent with the maximization of a continuous, concave, strongly monotonic utility function.

Figure 1 shows why we need to strengthen the original requirements of weak monotonicity and local nonsatiation to strong monotonicity. Suppose  $a$  and  $b$  are chosen from the choice sets  $A$  and  $B$  respectively, where each choice set consists of the bundles indicated by the dots that are connected by the respective line. By weak monotonicity we can conclude  $u(a) = u(b)$ , since when  $a$  is chosen something at least as good as  $b=(2,3)$ , namely  $d=(2,4)$ , was in the choice set. However, this is not enough to reject rational choice, since the only other thing we know is that  $u(b) = u(a)$ , by similar logic, and if  $u(a) = u(b)$  then neither of these choices is irrational. Local nonsatiation does not add any bite here, since it only requires that there be *some* alternative within any given distance of  $b$  that provides higher utility: it does not require that the alternative actually be in the choice set.

However, if we assume utility functions are strongly monotonic, we *can* use revealed preference to test rationality. Now we can use these choices to say  $u(a) > u(b)$ , since  $a$  was chosen over  $d$ , which by strong monotonicity must provide more utility than  $b$ . A similar argument would imply  $u(b) > u(a)$ , since  $b$  was chosen over  $c=(4,2)$  which must provide more utility than  $a=(3,2)$ . The contradiction means that these choices cannot be the result of rational choice.

In addition to counting violations, for consistency with other papers we report a version of Afriat's (1972) efficiency index, a measure of the severity of the GARP violations.<sup>2</sup> This measure was developed in the context of budget sets, and is based on the fact that a choice that violates revealed preference can be interpreted as a waste of money. When a revealed preference violation occurs, the person could have made some alternative choice that they revealed they preferred, instead of the choice they actually made. The cheaper this alternative is, the more money was wasted by not choosing rationally. The index  $e$  measures the overall efficiency of the participants' choices, or  $1-e$  measures the proportion of income that a person wasted by making the choice that violated revealed preference. An index of one means either no violations or that an infinitesimally

small change in a choice would eliminate all violations. A discussion of the advantages and disadvantages of this index is available in Varian (1991).

To calculate this index with our choice data we use the implicit prices and incomes from which our choice sets are derived, and we make the simplifying assumption that the choice sets are continuous. Revealed preference violations and the efficiency index were obtained by using an algorithm that was modified from Varian (1995), and which is available from the authors.

## **II. Previous Experiments**

Economists have done many studies to test whether observed choice data can be reconciled with the axioms of revealed preference. Some studies have looked at changes in household consumption in response to market price and incomes fluctuations. Such empirical studies tend to have little power to reject rational choice, because the observed price fluctuations are so small and because the data used typically lumps goods into categories. A classic early experimental alternative is Raymond C. Battalio et al. (1973), which used data on consumption choices by women inmates at a psychiatric hospital. The participants bought goods at a commissary, and the authors arranged to have the prices of goods periodically changed by large amounts, and records kept of individual purchases. Depending on the way in which errors in the recording of choice decisions are accounted for, they found that between 5 and 50 percent of the participants made choices that violated revealed preference.

One problem with this study, and similar studies that use either controlled or market induced price fluctuations is that if preferences change over time choices made at different times cannot be used to test for rational choice. Two more recent papers have used a random lottery procedure to avoid this problem. This procedure involves giving the participant a list of intersecting budget sets, only one of which will be actually implemented. The participant's problem is to choose so as to maximize expected utility. So long as preferences are independent of irrelevant alternatives, this procedure elicits the data necessary for checking consistency with the revealed preference axioms, namely the participant's most preferred alternative from a variety of different sets of alternatives.

James Andreoni and John Miller (1998) used this procedure to look at 142 college students' decisions about how much money to keep for themselves and how much to share with another under 8 different budget constraints. They found that 9 percent of the participants had some violations of the revealed preference axioms. Reinhard Sippel (1997) studied 42 college students' choices for 8 different consumption goods, using 10 different budget sets. He found that 24, or more than half of the participants violated GARP.

Developmental psychologists have also done work on intransitivity in children, but with a very different focus. The typical experiment is designed as a test of reasoning, not of choice, and involves either questions like "If Ted is older than Bill, and Bill is older than Jim, then who is older, Ted or Jim?" or similar comparisons of the length or weight of objects. The general conclusion of the literature, as reviewed in Leonard Breslow (1981), for example, is that while it is difficult to measure this ability while controlling for the development of general verbal skills, it appears to develop between the ages of 7 and 9. It seems quite possible that a child could perform poorly at transitive reasoning, yet be perfectly able to avoid intransitive choices.

There is also a related literature on choice by animals, focusing on whether choices by pigeons and rats obey the laws of demand, summarized in John H. Kagel et al. (1995). Typically, in these experiments food is allocated by pushes on levers, and incomes and prices are varied by limiting the number of allowed lever pushes and varying the amount of food dispensed per push. The participants are given one budget constraint for about two weeks at a time, by which time consumption has stabilized. Then the constraint is changed. A typical experiment would involve testing for an inverse relationship between price and quantity by imposing a new budget constraint passing through the original consumption bundle, but with different relative prices. They find 87 percent of the rats and 81 percent of the pigeons reduce consumption of a good when given an income compensated price increase. Note that this test of rational behavior is much less rigorous than those done on humans.

### **III. Protocol and Participants**

Our experiment is similar in design to those of Andreoni and Miller and of Sippel. We

presented our participants with 11 different choice sets. Each choice set was a list of between three and seven bundles, with each bundle consisting of a number of small bags of potato chips and a number of boxes of fruit juice. We used goods that would typically be consumed quickly because we wanted as little possible interaction between decisions in the experiment and outside influences. Figure 2 shows the choice sets as dots representing the bundles included in each choice set. As can be seen by the lines connecting the dots, the choice sets we used consisted of all the integer combinations of bundles on the frontier of a budget set that was determined by a fixed income and prices.

The participants were given a stapled packet, with each page listing the bundles for a single choice set. We told them they would be asked to circle the bundle that they liked best from each page. After they were done choosing we would pick one page, and they would get to actually keep the bundle they picked from that page. Sufficient supplies of chips and juice were shown to make this promise credible. We told them not to mark their choice until 30 seconds were up, and to spend any extra time looking over the bundles and making sure they had really picked the one they liked best. It was clear that 30 seconds was more than enough time to allow for careful decisions.

After we had gone through all 11 choice sets, we repeated the procedure, this time giving them 15 seconds for each choice set. We told them to think some more about the bundles, and make any changes they wanted to. We then picked one choice set, showed it and their choice to the participant, and gave them a third and final chance to change their chosen bundle. They were then given that bundle in a paper sack. The script and details of the experiment are in the appendix.

This protocol provides the sort of data necessary for testing rational choice, namely multiple observations of individual choices from intersecting choice sets. Since there is a probability that every choice will be implemented, the participants have an incentive for making choices that actually represent their preferences.

The experiments were done on 31 second grade students and 42 sixth graders in Eugene, Oregon public schools, and also on 55 college undergraduates at the University of Oregon. We did not record individual ages, but second graders are generally about 7 years old, sixth graders about 11, and these undergraduates average about 21. The grade school experiments were arranged with the permission of cooperative teachers, and all students in their class that day participated. Since

school attendance is mandatory, and the proportion of children in private and home schools is small, this method of recruiting participants ensures that our sample of children is very representative of the local population.

The undergraduates were included to provide a plausible upper limit, for this protocol, against which the amount of rationality in children's choice performance could be compared. We first tried using performance by graduate students and faculty in economics as our standard. However, these participants all had some familiarity with revealed preference theory, and in post experiment interviews they stated that they were primarily concerned with avoiding what they saw as embarrassing violations of rationality, and only secondarily with getting the bundles of goods that they preferred. This preference clearly affected their behavior – most picked corner solutions, explaining later that they knew this would ensure their choices would satisfy GARP. (Those who did not adopt this strategy did exhibit some violations of revealed preference.) To provide a more realistic baseline we ran the comparison experiment on undergraduate economics majors. This was done at the first meeting of an undergraduate intermediate microeconomics class and before any mention of revealed preference theory.

The undergraduate experiments were run with the same protocol as were the experiments on children. We should note that college undergraduates are not only older than the children, but are also a more select group in terms of mathematical ability and general intelligence. On the other hand, they are probably less motivated by the actual consumption of these particular goods. Still, they were clearly interested, and were willing to wait in line for as long as 5 minutes after the completion of the experiment to get their chips and juice. We believe that their performance is close to the maximum degree of rationality that we should reasonably expect to find in adults using this protocol.

#### **IV. Results and Discussion**

We use the results for the participants' final choices.<sup>3</sup> In the protocol, the bundles from each choice set were always presented to the participants in descending order by the number of juice boxes. We used a consistent order so that participants could quickly grasp the possible

consumption choices without having to search through the bundles. To check that the order in which the choice sets were presented did not affect violations we showed the choice sets in 4 different orders. We found that orderings did not have significant effects on the severity index or on the number of violations of any of the tests of revealed preference (nor on preferences for one good over another.)

Table 1 shows average violations of GARP for the 3 different age groups. The last two lines of the table gives results for two different versions of random choice, each with 10,000 observations, where each observation consists of one choice from each of the 11 different budget sets. For the first version we pick each observation's choice from a given choice set randomly and with equal probability from the set of possible choices in that set. The second is a boot-strap type simulation. For each of these observations the choices for a given budget set are drawn using weights reflecting the proportion of our sample making that choice from that budget set. This gives a measure of the number of violations that would be expected from random choice, while incorporating information about people's actual choices, rather than just the possible alternatives.

Four results are apparent from this table. Some revealed preference violations are present at all ages. Even the youngest children have considerably fewer and less severe violations than would be expected if they were choosing randomly. The number of violations decreases noticeably from age 7 to 11. From age 11 to 21, there is only a small and insignificant further decrease in the rationality of choices.

We then ask whether the violations are driven by a few people making many violations, or by small numbers of violations by many people. Table 2 shows the distribution of the number of GARP violations, again across the age groups. The distribution from the random choices is included for comparison.

The distribution of violations in our participants is clearly very different than that from random choice. Even for second graders, the group with the most violations, 26% of the participants have no violations, compared to 2% under bootstrapping. For this particular test of rationality, we can say that about 25% of the 7-year-olds and about 60% of 11-year-old participants make choices that are consistent with utility maximization. We can also say that for this test there is no real increase in rational choice from age 11 to 21.

While the temptation is difficult to resist, we cannot use this table to conclude anything like “only 26% of second graders can choose rationally” or “11-year-olds are more than twice as likely to choose rationally as are 7-year-olds.” Our experiment is only one of a variety of possible tests, and participants who pass this test might well fail a more rigorous one. Similarly, we cannot conclude that, in general, rational choice does not substantially increase from the age of 11 to 21. We might well expect a larger increase with a more rigorous test, though it is also conceivable that we would find a smaller one.

The test by Sippel is more difficult than ours in that it involves choices from nearly continuous budget sets over 10 goods rather than just 2, but he also gives the participants more time to decide (he used 20-30 minutes, versus 9 or so in our protocol). Given these countervailing factors, his result that 57% of the participants violate GARP seems generally consistent with what we find. Andreoni and Miller’s study of altruistic choices finds GARP violations in only 9% of the participants. Their participants face 8 budget sets rather than the 11 in our experiment, and perhaps preferences over sharing are better defined even than those over familiar consumption goods.

Last we address the question of whether children with better mathematical ability are better at choosing. Our measure of mathematical ability is performance on the multiple-choice part of the Oregon Mathematics Problem Solving Assessment Test. This is an hour-long test that was designed to measure student achievement and was administered to the sixth graders when they were in fifth grade. We had data for 37 of the 42 sixth grade participants. The mean score was 227 and the standard deviation was 11. Table 3 shows the results of regressions of the number and severity of GARP violations in the last round against performance on this test score. Nearly identical results were found for the first round. While in both regressions the coefficient had the “correct” sign, in the sense that higher mathematical ability was correlated with more rational choices, neither effect was significant. We also found that performance on this test was not significantly correlated with the number of choices that were changed between the first and last rounds of the experiment. In addition, students with higher scores were not more likely to decrease their number of violations, either in general or conditional on the number of changes.

## V. Conclusion

The argument that people behave rationally is central to economics, and the experiment reported in this paper is perhaps the simplest possible test of economic rationality. It requires no ability to forecast choices by others and act strategically, and no ability to think about time or probability in any rigorous way. We just ask people to choose what bundle of goods they like from a list of a few alternative possibilities – in our protocol, they do not even need to do the math needed to stay within a budget constraint.

Using this experiment, we find that at age 7 children's choices about consumption goods show clear evidence of rationality, though also many inconsistencies. By age 11, choices by children with below average mathematical ability are as rational as choices by adults with above average intelligence, although even these adults' choices show many inconsistencies. Based on our results, we conclude that, to the extent the assumption of utility maximization is useful for modeling choice behavior by adults, it is also appropriate for children. We are not claiming that children's behavior in more complicated economic situations, for example those involving choices over time or uncertainty, or requiring strategic behavior, can be described using the same models as are used for adults. These issues are subjects for future research.

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## **Appendix**

### **Protocol:**

[Before experiment: Prepare cards, label seats with numbered post it notes. Teacher introduces Tim, asks students to cooperate with him.] Hi everyone, my name is Tim. Today in class we're going to play a game. By playing the game you will get some juice boxes and bags of potato chips. [Show the available juice and chips.] You don't have to play this game if you don't want to. If during the game you decide that you want to stop, just let me or your teacher know. We will find something else for you to do. [See if anyone opts out.] Before we start the game, I want to scramble everybody up. I'm going to shuffle these cards and give each one of you one card. When you get your card, sit at the seat with the same number as your card. [Help students find their seats.]

The game is very simple. You don't play against anyone. You just choose how many bags of chips and juice boxes you want from a list that I will pass out later. Then when the game is over, we will give you the juice boxes and bags of chips that you choose. Let me show you how it works. I'm now going to pass out a piece of paper. Pretend this is a test, and don't look at anyone else's paper. [Pass out paper.] This paper is just like the ones we will use in the real game. But right now we are just playing for practice. We will tell you before we start the real game. [Show overhead.] On this practice paper you have five choices. Each choice is either all chips, all juice boxes, or some juice boxes and some chips. We will call each choice a bundle. Your job is to pick the bundle that you like the best. [Indicate these alternative bundles on the overhead.] Here are some bundles. You can either get five juice boxes and no chips, Four juice boxes and 1 bag of chips, Three juice boxes and two bags of chips, Two juice boxes and three bags of chips, One juice box and four bags of chips, Or no juice boxes and five bags of chips.

We want you to think carefully about which of these bundles you like the best. Would you rather have 5 juice boxes and no chips, or 4 juice boxes and one bag of chips? Would you like 3 juice boxes and 2 chips better yet? I want you to look at all 5 of the bundles, and choose the one bundle you like the best. When we start the real game, we are really going

to give you the juice boxes that you choose. So you want to think carefully before you choose a bundle. We will give you 30 seconds to choose. If you choose right away, we want you to use the extra time to think some more about the bundles. Make sure you have really picked the one you like best. When the thirty seconds are up, I'll tell you to circle the bundle you choose. Ok, for practice, I'm going to give you 30 seconds, starting now, to think about your choice. Remember, no talking! [Wait 30 seconds, tell them to circle their choice, Answer any questions.]

OK, Now we are almost ready to start the real game. It's just a little more complicated than the practice one. You are going to get eleven pieces of paper. Each one is a lot like the one you just got. The only difference is that the bundles are different on each piece of paper. On each piece of paper I want you to choose the one bundle you like the best, just like in the practice. For each piece of paper, I'll give you 30 seconds to choose. When the thirty seconds are up I'll tell you can go on to the next page. When you've made one choice from each of the eleven pages, I'm going to pick one of the pieces of paper and you will get whatever you circled on that piece of paper. You don't know which piece of paper I'll pick, so the best thing for you to do is to pick the bundle that you like the best from *every* piece of paper, in case that's the one I pick. Are there any questions? [Answer their questions.]

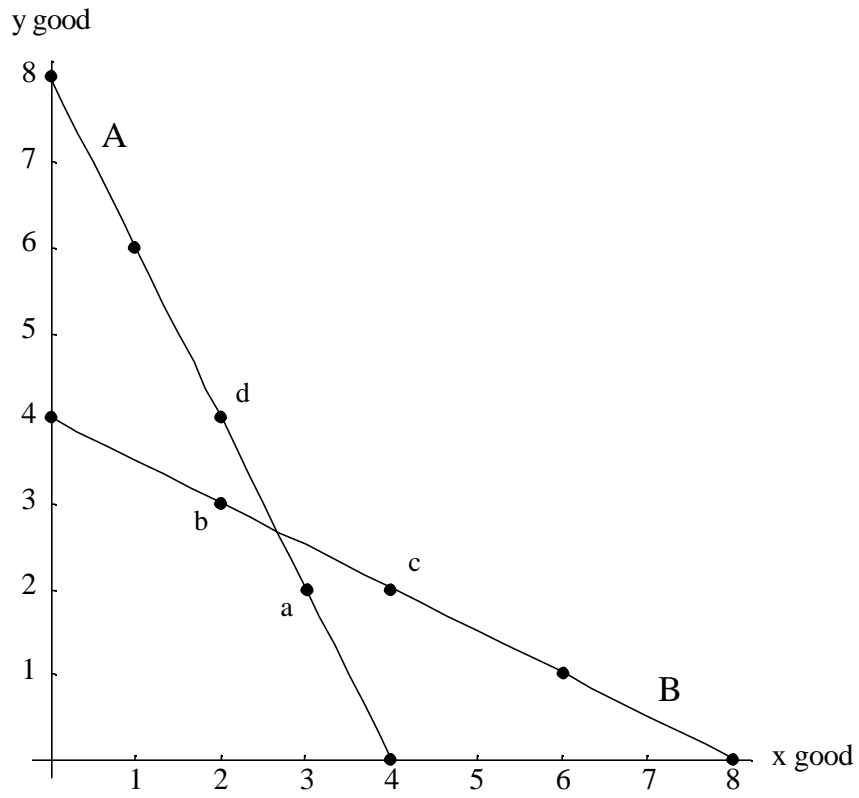
I'm now going to pass out the paper now. Put your name on the first page, and don't turn the page until I tell you. [Pass out paper, make sure everyone has written their name.]

Remember, this is just like a test. Please don't talk to anyone. Also, we don't want you to look at anyone's paper except your own. Now, turn to page 1. You have 30 seconds to make your choice. [After 30 seconds, proceed to next page until done.] Ok, is everybody finished? Now, just to make sure that you picked your favorite choice on every sheet of paper, we're going to go through the choices again. I want everybody to go back to the page with his or her name on it. Just like before, wait for me to tell you to turn the page. This time I'll give you 15 seconds for every page. If you make a change, cross out your old choice with an X and circle your new choice. Don't erase your old answer. Are there any questions? [Answer their questions.] Ok, start on page 1. [After 15 seconds, proceed to

next page until done. Collect pages.]

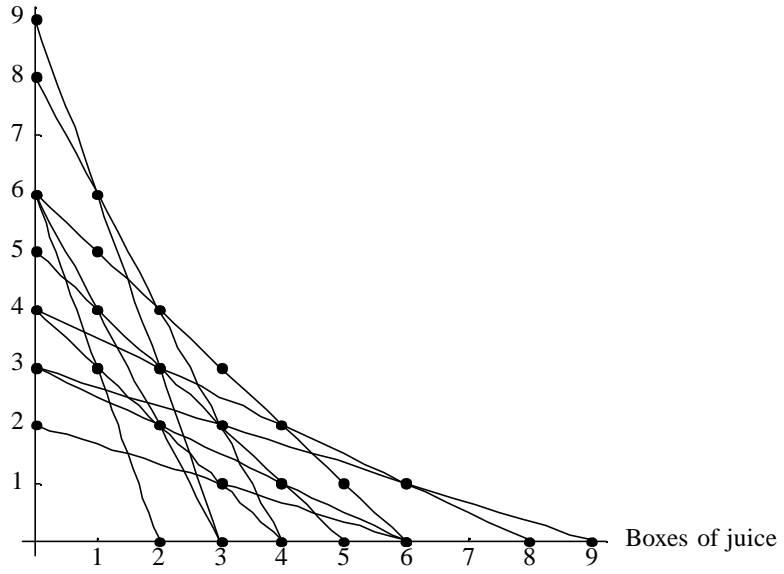
Ok, I pick page \_\_\_\_ as the page. You'll get whatever bundle you picked on that page. When I call your name, come over to the corner and we'll give you your bundle. Please don't open it until everyone has had a chance to get his or hers. [Do the distribution in brown lunch bags, so no one can see other's choices. When kids come to the corner, say the following.] Ok, we just want to make sure you are getting the bundle you like the best. [Show them their page.] Of all these bundles, are you sure you want this one? [Point to their choice.] We're not trying to get you to change your mind, but if after looking at the bundles one last time you want to change your mind and pick another one, this is your last choice. [If they change, mark the new choice in red.]

**FIGURE 1. REVEALED PREFERENCE WITH DISCRETE CHOICE SETS**



**FIGURE 2. CHOICE SETS**

Bags of chips



**TABLE 1. AVERAGE REVEALED PREFERENCE VIOLATIONS, BY AGE**

Group	Average numbers of GARP violations	Afriat's Index
2 <sup>nd</sup> graders	4.3	0.93
6 <sup>th</sup> graders	2.1**	0.96
Undergraduates	2.0	0.94
Random (uniform)	8.91	0.648
Random (bootstrapping)	8.29	0.749

Notes: The mean numbers of violations and the mean of Afriat's Index for all the age groups are less than for random choice at the 1% significance level, using t-tests. For the age groups, \*\* indicates significantly different from the mean directly above at the 1% level.

**TABLE 2. PERCENTAGE OF GROUP WITH DIFFERENT NUMBERS OF GARP VIOLATIONS**

Number of GARP violations	<u>Percentage of group with violations</u>			
	2 <sup>nd</sup> graders	6 <sup>th</sup> graders	Undergraduates	Random (bootstrapping)
0	26	62	65	2
1	0	0	0	0
2	3	7	2	5
3	10	5	9	4
4	6	0	0	9
5	26	7	13	11
6	0	7	2	15
7	6	2	0	17
8	10	5	0	17
9	10	2	4	12
10	3	2	2	7
11	0	0	4	2

**TABLE 3. RATIONALITY VIOLATIONS AND MATHEMATICAL ABILITY IN 6<sup>TH</sup> GRADERS**

	Average numbers of GARP violations	Afriat's Index for GARP
Math score	-0.0323 (0.0462)	0.000940 (0.00179)
R-sq	0.014	0.0078

(37 observations)

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<sup>1</sup> Samuelson's result used the Weak Axiom of Revealed Preference, which only makes direct comparisons between choices and does not allow indifference curves to have straight segments. Houthakker used the Strong Axiom of Revealed Preference, which allows indirect comparisons but maintains the indifference curve assumption. GARP allows for both indirect comparisons and straight segments of indifference curves. The conclusions in this paper are the same using any of these definitions of rational choice.

<sup>2</sup> We count violations using what we see as the simplest method. For each of the choices we count one violation as occurring if that choice, in combination with *any* of the other choices, violates GARP. An alternative would be to count each such violation separately.

<sup>3</sup> We also looked at whether changes in choices led to fewer violations. The second graders made an average of 2.0 changes, sixth graders 1.2, and undergraduates 0.75. For each grade we regressed the final number of violations against the initial number of violations and the number of choices that were changed. For all grades the coefficient on the initial number of violations was positive and significant, while that on the changes was negative and significant for the second graders and actually positive, but insignificant, for the older kids and undergraduates. We interpret this to mean that the older participants who change their choices do not have strong preferences over these goods to begin with. We think the close similarity of these results for sixth graders and undergraduates strengthens the conclusion that these groups have similar choice behavior.