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ECARES working paper 2012-050

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Are the smart kids more rational?*

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December 11, 2012

Abstract

We conducted an experiment to collect data on consumption decisions made by children of different age categories. In particular, our experiment involves unsophisticated discrete consumption choices, and we present a rationality test that is specially designed for the resulting choice data. Our first conclusion is that, in general, the observed children's consumption behavior is largely irrational. Next, we also investigate the relationship between the degree of rationality and the children's characteristics. Specifically, we use teacher based assessments on several personal characteristics to investigate whether and to what extent smart children tend to behave more rational. Here, our main conclusion is that it is important to recognize the multidimensional nature of intelligence to obtain a balanced insight into the effect of intelligence on rationality.
JEL Classification: C14, C91, D12.
Keywords: rationality, children, revealed preference, intelligence.

1 Introduction

We use experimental data to study the "rational" consumption behavior of children. Considering children of different ages, we assess the empirical validity of the rationality assumption. Next, we also explain the degree of rationality in terms of the children's personal characteristics. In this respect, a specific feature of our study is that we relate rational consumption to alternative dimensions of intelligence. In particular, we investigate how verbal skills (language) and non-verbal skills (mathematics) define the (ir)rational consumption behavior of children. Or putting it differently, are the "smart" kids more rational? And, if so, does the type of smartness matter? This introductory section motivates our research question, and indicates how this study relates to the existing literature.

Motivation. The literature has devoted considerable attention to studying whether economic models are applicable to children.[1] The aim is to understand the children's decision behavior, and to gain insight into the evolution of this behavior when children grow older. Clearly, a better understanding of children's economic behavior allows for a better modeling of this behavior. For instance, household consumption models that

*We benefited from discussions with seminar participants in Leuven. We thank Pieter Markey for able research assistance. We are also grateful to the Fund for Scientific Research - Flanders (FWO-Vlaanderen) for financial support.

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[1]See, for example, Harbaugh, Krause and Berry (2001), Harbaugh, Krause and Liday (2003), Harbaugh, Krause and Vesterlund (2002, 2007), Farrell and Shields (2007), Lundberg, Romich and Tsang (2009), and references therein.

include children usually treat these children as either some "public good" entering their parents' utility functions or as rational decision makers maximizing their own utility.[2] This immediately raises the question whether and to what extent children can actually be considered as rational consumers. We refer to Harbaugh, Krause and Berry (2001) and Lundberg, Romich and Tsang (2009) for a more elaborated discussion of this type of arguments.

Next, there is the obvious observation that children often do have to make consumption decisions (e.g. on how to spend their pocket money or how to choose the games they play). In this respect, Choi, Kariv, Müller and Silverman (2011) argue, rather convincingly, that the quality of such consumption choices can be measured by the degree of rationality. In particular, they show that irrational choices imply a "waste of money". In a similar vein, Echenique, Lee and Shum (2011) indicate that irrational consumers are subject to being exploited as a "money pump". This pleads for protecting and guiding children's behavior more carefully if this behavior turns out to be largely irrational. In this respect, identifying the children's characteristics that drive rationality can also lead to more effective protection and training of those children who are particularly vulnerable.[3]

Methodology and related literature. Observational "real-life" data usually do not contain sufficient information on children's consumption to study rationality of their behavior. Therefore, most papers cited above make use of experimental data to study children's behavior.[4] In line with this common practice, we also conduct an experiment in the current study. Specifically, for each individual child we gather data on 9 (unsophisticated) discrete consumption choices. As we will indicate, this experimental setup effectively allows for a powerful test of rationality.

Our experimental design is similar to the one of Harbaugh, Krause and Berry (2001), who also focused on verifying whether children can be modeled as rational decision makers. However, it is worth emphasizing two main differences between these authors' study and ours, which -in our opinion- makes our study a valuable extension of this original one. Firstly, as for our testing methodology, we use a different procedure to check rationality, which is specially tailored for discrete choice settings such as ours. Secondly, and more importantly, our experimental data set is richer than the one of Harbaugh, Krause and Berry in that it includes more detailed information on the children's personal characteristics. Most notably, as indicated above, we have information on alternative dimensions of child intelligence. As we will explain, this effectively provides a more balanced insight into the driving forces of economically rational behavior. It will turn out to be important to explicitly account for the multidimensional nature of intelligence to identify significant effects.[5]

At the methodological level, we use so-called "revealed preference" tests to check rationality of the children's consumption behavior.[6] A particular feature of this revealed preference approach is that it starts directly from the observed choices and does not require any functional specification of the individual preferences. It directly verifies the testable implications of rationality on the raw consumption data. Conveniently, this avoids that rationality of observed behavior is rejected simply because of functional misspecification. Moreover, revealed preference tests can be meaningfully applied to small data sets. For our experiment, this means that we can analyze rationality of choices for each child separately and, thus, that we can avoid the debatable assumption that (e.g. observably similar) children have homogeneous preferences. Finally, and

[2] For example, Blundell, Chiappori and Meghir (2005) and Cherchye, De Rock and Vermeulen (2012) propose household consumption models that treat children as public goods, while Becker (1974), Dauphin, El Lahga, Fortin and Lacroix (2011) and Dunbar, Lewbel and Pendakur (2012) consider models that assume children are individually rational decision makers.

[3] For example, Choi, Kariv, Müller and Silverman (2011) argue that insight into the relationship between rationality and personal characteristics can prove useful to design appropriate social programs (Manski, 2001) and paternalistic policies (Thaler and Sunstein, 2003).

[4] One exception is the study of Farrell and Shields (2007), which uses child diary information contained in the British Family Expenditure Survey. However, the cross-sectional data used by these authors do not allow for testing the rationality of the children's decision behavior itself.

[5] In this respect, Harbaugh, Krause and Berry (2001) only considered the effect of mathematical skills in their original study, and their results did not reveal a significant relation between rationality and mathematical ability. In Section 5, we will indicate that the effect of mathematical ability on rationality only appears significantly if one controls for differences in verbal skills (in our case language). This shows the importance to simultaneously account for multiple dimensions of intelligence when studying its effect on rationality of consumption behavior.

[6] See Samuelson (1938), Houthakker (1950), Richter (1966), Afriat (1967), Diewert (1973) and Varian (1982) for seminal contributions on the revealed preference approach that we adopt here.

also because of these reasons, it has been argued in the literature that revealed preference tests are specially useful within an experimental context such as ours.[7]

Paper outline. Section 2 describes the specificities of our experiment. As indicated above, we confronted each child with 9 choice problems. In each problem, the child had to choose between 7 commodity bundles, which makes that we observe 9 consumption choices in total. In this section, we will also explain how we obtained our variables on the children's personal characteristics. In particular, following the argumentation of Hoge and Coladarci (1989) we use teacher assessments to construct our indicators of intellectual skills.

Section 3 presents our revealed preference test of rationality. Because our experiment involves discrete choices, we cannot straightforwardly apply the usual revealed preference tests, which are designed for standard (continuous) budget sets.[8] Therefore, we develop an adapted revealed preference test that can deal with our type of discrete choice data.

Section 4 presents the results of our revealed preference tests for the children in our sample. We discuss pass rates and discriminatory power of our test. In addition, if a child's observed consumption behavior turns out to be irrational, we measure how close it is to rationality by using Afriat's "cost efficiency index".[9] Intuitively, this index evaluates the degree of rationality by the amount of money that is wasted by making irrational decisions. Adopting the argument of Choi, Kariv, Müller and Silverman (2011) that we cited above, this index thus quantifies the "quality" of the observed consumption decisions.

Section 5 investigates the personal characteristics that drive rational behavior. A particular focus is on the question whether and to what extent "being smart" relates to "being rational". A main finding here will be that such an investigation must take the multidimensional nature of intelligence (verbal versus non-verbal skills) into account. Section 6 concludes.

2 The experimental data

In this section, we first describe how we obtained our data on children's personal characteristics. Next, we explain our experiment to collect (discrete) choice data. We will also indicate how this experimental design impacts on the revealed preference test that we present in Section 3.

Personal characteristics. Our sample includes a total of 100 children residing at four different schools that participated to our experiment (39 from kindergarten, 31 third graders and 30 sixth graders). Child ages range from 5 to 12 years, with a mean value of approximately 8 years. Hoge and Coladarci (1989) argue that teacher based assessments form a reliable source of information on children's characteristics.[10] Following their argumentation, we asked teachers about each child's intellectual skills, which include language as a verbal skill and mathematical ability as a non-verbal skill. We also consider creativity as an additional dimension of intelligence.[11] Next, we also asked for the number of older siblings in the child's family. We will motivate our use of data on older siblings in Section 5.

We used two different indicators to quantify the four intellectual skills. The first indicator has possible scores ranging from 1 (= bottom 2 % compared to peers) to 8 (= top 2 % compared to peers), and the second indicator has possible scores ranging from 1 (= very weak compared to peers) to 10 (= very strong compared to peers). See Appendix A for more details. Our following empirical exercises will make use of a composite of these two indicators, which is constructed in two steps. First, we transformed (i.e. multiplied by 10/8) the scores for the first indicator so that they also ranged from 1 to 10. Subsequently, our composite skills indicators are computed as the average of these transformed scores for the first indicator and the original scores for the second indicator.

[7]See, for example, Sippel (1997), Harbaugh, Krause and Berry (2001), Andreoni and Miller (2002) and Bruyneel, Cherchye and De Rock (2012). Cox (1997) also provides an extensive discussion on the use of revealed preference methodology in combination with experimental data.

[8]See, for example, Varian (1982) for more discussion on standard revealed preference tests.

[9]See Afriat (1972) and Varian (1990, 1993) for a discussion of this cost efficiency index.

[10]In fact, Borkenau and Liebler (1993) argue that acquaintances can, quite accurately, assess a person's intelligence. In a recent paper by Lonnqvist, Vainikainen and Verkasalo (2012), for instance, teacher and parent ratings are used to evaluate the cognitive abilities of children.

[11]The triarchic theory of intelligence (Sternberg, 1985), for instance, stresses the importance of creativity.

Table 1 provides summary information on the children's personal characteristics for our sample. Generally, for the different characteristics we obtain quite some variation across the participants of our experiment. This observation is particularly useful in view of our explanatory analysis in Section 5, where we will relate this variation to differences in rationality of the children's consumption behavior.

	obs	mean	std dev	min	max
age	100	8.04	2.825	5	12
mathematics	99	7.364	1.686	2.75	10
language	99	7.283	1.601	2.75	10
creative	99	7.24	1.489	3.875	10
older siblings	93	0.935	0.987	0	5

Table 1: Summary statistics for personal characteristics

Experimental design. As indicated in the Introduction, our experiment is similar in design to the one of Harbaugh, Krause and Berry (2001). As a starting point, we take from these authors that it does not seem appropriate to ask the participants of our experiment to select commodity bundles from a continuous budget set (defined by given prices and budget). Because such a selection process involves abstract mathematical reasoning, this seems too difficult a task for young aged children.

To account for this difficulty, we confronted the children in our experiment with 9 unsophisticated discrete choice problems, each characterized by a choice set C_t consisting of (only) 7 consumption bundles. More precisely, we conceived 9 different price regimes. For a fixed budget, each such price regime defines a budget hyperplane. Then, we selected 7 quantity bundles from every budget hyperplane, and in each choice problem we asked the children to pick their preferred bundle from these 7 bundles. Thus, our experiment is such that children did not face *explicit* prices and budgets when selecting their consumption bundles, but we can interpret their choices as defined under *implicit* prices and budgets. Clearly, this considerably facilitated the children's decision process; they simply had to select 9 commodity bundles from choice sets C_t that contained only 7 elements.

More specifically, the children could choose quantity bundles that were composed of three commodities: grapes (units of 10 grams), mandarins (units of 12.5 grams) and letter biscuits (units of 5 grams). The 7 bundles in a given choice set always contained the three "extreme" bundles with all budget spent on a single commodity, and four other "intermediate" bundles with positive quantities for our three commodities. Appendix B reports the choice sets we used and the associated (implicit) prices. In Section 4, we will argue that these choice sets imply a powerful revealed preference test of rationality.

The whole experiment is carried out in the classrooms of the four participating schools. Each child is invited to taste the grapes, mandarins and letter biscuits prior to the experiment. These tasted commodities are of the same brand and have the same quality as the commodities in the actual decision problems. Finally, the children were truthfully told that, at the end of the experiment, they would receive one consumption bundle that would be taken randomly from the 9 bundles they selected. This should guarantee that the children's choices in the experiment effectively reveal their true preferences over the commodity bundles. We provide more details on our experiment in Appendix B. Importantly, given our specific setup, we may safely abstract from intertemporal issues like savings and interdependent consumption choices.

Table 2 provides summary information on the individual budget shares of the three different commodities. The fact that children chose positive amounts of all commodities makes us conclude that each commodity is effectively desirable. On average, the letter biscuits commodity seems to be the more popular one. However, the reported standard deviations also reveal quite some heterogeneity over the choices made. Generally, all this suggests that our experimental data provide a useful basis to assess rationality of consumption choices.

Table 2 also gives separate budget share information for the girls and boys in our experiment. It seems that there are no specific gender effects in terms of the commodities that are selected. Actually, this is a systematic finding for our sample of children: for none of the exercises discussed in Sections 4 and 5, we found significant differences between girls and boys. Therefore, and to compactify our exposition, we will not report on gender effects in these following exercises. Evidently, results for the subsamples are available from the authors upon simple request.

	grapes	mandarins	letter biscuits
all children	.317	.245	.438
	(.172)	(.190)	(.258)
kindergarten	.273	.174	.553
	(.204)	(.180)	(.284)
third grade	.312	.235	.452
	(.117)	(.173)	(.208)
sixth grade	.378	.347	.275
	(.159)	(.179)	(.178)
girls	.307	.245	.448
	(.170)	(.184)	(.263)
boys	.329	.244	.427
	(.175)	(.199)	(.255)

Table 2: Average budget shares (standard deviations between brackets)

As a final point, it is worth noting that our discrete choice setting raises some particular issues. Firstly, it could well be that for a number of children the 7 options in some choice problem did not include the children's most preferred bundle defined over the entire budget set associated with the corresponding (implicit) prices and budget. However, during our experiment it was clear that our selection of choices strikes a right balance between simplifying the problem and exhausting all budget possibilities (see also our empirical analysis in Section 4). Secondly, and related to this, standard revealed preference tests assume continuous budget sets, while our setup implies discrete choice sets. This makes that we need an adaptation of the standard revealed preference test of rationality, which we discuss next.

3 A revealed preference test of rationality

As explained in the previous section, the children where faced with 9 different discrete choice sets C_t. Each choice set contained 7 quantity bundles taken from a budget hyperplane.[12] And the children had to choose one quantity bundle $\mathbf{q}_t \in \mathbb{R}^3_+$ (with $t = 1, \ldots, 9$) from this set. For each individual child, this defines the data set

$$S = \{(C_t; \mathbf{q}_t), t = 1, ..., 9\}.$$

The data set S is consistent with rationality if there exists a well-behaved (i.e. continuous, concave and strictly increasing) utility function U which rationalizes the data, in the following sense.

Definition 1 *Let $S = \{(C_t; \mathbf{q}_t); t = 1, ..., 9\}$ be a set of observations. A well-behaved utility function U provides a* rationalization *of S if and only if for each observation $t = 1, ..., 9$ we have $U(\mathbf{q}_t) \geq U(\mathbf{z})$ for all $\mathbf{z} \in C_t$.*

Note that, although we used implicit prices and budgets to design the experiment (i.e. to describe the hyperplanes used in the construction of the choice sets C_t), we do not make use of this information in our definition of rationality and, thus, we cannot use this information in the corresponding revealed preference test of rationality. As an implication, our test results will not depend on the fact that the children were not aware of the actual price-budget information.

The following concepts will be crucial ingredients of our revealed preference test of rationality.

Definition 2 *Let $S = \{(C_t; \mathbf{q}_t); t = 1, \ldots, 9\}$ be a set of observations. Then for any $s, t = 1, \ldots, 9$:*

(i) *$\mathbf{q}_t$ is directly revealed preferred over $\mathbf{q}_s$ (i.e. $\mathbf{q}_t R_0 \mathbf{q}_s$) if there exists a $\mathbf{z} \in C_t$ such that $\mathbf{z} \geq \mathbf{q}_s$;*

[12] More precisely, there exist (implicit) prices $\mathbf{p}_t$ and an (implicit) budget y_t such that, for all $\mathbf{z} \in C_t$, $\mathbf{p}_t\mathbf{z} = y_t$.

(ii) $\mathbf{q}_t$ *is strictly directly revealed preferred over* $\mathbf{q}_s$ *(i.e.* $\mathbf{q}_t P_0 \mathbf{q}_s$*) if* $\mathbf{q}_t R_0 \mathbf{q}_s$ *and* $\mathbf{q}_s \notin C_t$*;*

(iii) $\mathbf{q}_t$ *is revealed preferred over* $\mathbf{q}_s$ *(i.e.* $\mathbf{q}_t R \mathbf{q}_s$*), if there exists observations* $u, v \ldots, w$ *such that* $\mathbf{q}_t R_0 \mathbf{q}_u$*,* $\mathbf{q}_u R_0 \mathbf{q}_v$*, ...,* $\mathbf{q}_w R_0 \mathbf{q}_s$*.*

Essentially, this definition makes clear the preference information we can extract from a child's observed choices contained in some data set S. The intuition goes as follows. As for statement (i), if the child chooses $\mathbf{q}_t$ in C_t, then (s)he must prefer $\mathbf{q}_t$ over all available bundles $\mathbf{z} \in C_t$. Because we assume strictly increasing utility functions (i.e. strongly monotonic preferences), this also means that the child prefers $\mathbf{q}_t$ over any $\mathbf{q}_s$ for which $\mathbf{z} \geq \mathbf{q}_s$. Statement (ii) builds further on the first statement and concludes from $\mathbf{q}_t R_0 \mathbf{q}_s$ that there exists $\mathbf{z} \in C_t$ such that $\mathbf{z} \geq \mathbf{q}_s$. Then, because $\mathbf{q}_s \notin C_t$ we must have that $\mathbf{z} \neq \mathbf{q}_s$, which means that $\mathbf{z}$ strictly dominates $\mathbf{q}_s$ in at least one commodity while not having less of any other commodity. Strictly increasing utility then implies that $\mathbf{z}$ is strictly preferred to $\mathbf{q}_s$, which carries over to $\mathbf{q}_t$ being strictly preferred to $\mathbf{q}_s$. Finally, statement (iii) imposes that preferences are transitive.

While Definition 2 resembles the standard definition of revealed preference relations (as, for example, in Varian (1982)), it is substantively different because it is defined in terms of discrete choice sets and does not use price information to reconstruct the preference relations. More precisely, let $\mathbf{p}_t$ and y_t represent the prices and budget information that describes the choice set C_t (i.e. for all $\mathbf{z} \in C_t : \mathbf{p}_t \mathbf{z} = y_t$). Then, it is easy to verify that $\mathbf{q}_t R_0 \mathbf{q}_\mathbf{s}$ (respectively $\mathbf{q}_t P_0 \mathbf{q}_\mathbf{s}$) implies that $\mathbf{p}_t \mathbf{q}_t \geq \mathbf{p}_t \mathbf{q}_s$ (respectively $\mathbf{p}_t \mathbf{q}_t > \mathbf{p}_t \mathbf{q}_s$). Importantly, however, the reverse implication does not hold necessarily, because the discrete choice set C_t does not contain all the bundles on the continuous budget hyperplane defined by $\mathbf{p}_t$ and y_t (i.e. the set $\{\mathbf{z} : \mathbf{p}_t \mathbf{z} = y_t\}$).

The following proposition defines a revealed preference test of rationality for our discrete choice setting. In particular, it provides a necessary condition for rationalizable consumption behavior that only uses information contained in the data set S. Appendix C contains the proof of the result.[13]

Proposition 1 *Let* $S = \{(C_t; \mathbf{q}_t)\,; t = 1, \ldots, 9\}$ *be a set of observations. Then, there exists a well-behaved utility function* U *provides a* rationalization *of* S *only if, for any* $s, t = 1, \ldots, 9$*,* $\mathbf{q}_t R \mathbf{q}_s$ *excludes* $\mathbf{q}_s P_0 \mathbf{q}_t$*.*

The revealed preference condition in this result states that, if some bundle $\mathbf{q}_t$ is revealed preferred over a bundle $\mathbf{q}_s$, then it cannot be that $\mathbf{q}_s$ is strictly directly revealed preferred over $\mathbf{q}_t$. In other words, we cannot have a cycle of revealed preference relations containing a direct revealed preference relation that is strict. The rationality condition in Proposition 1 is closely related to the Generalized Axiom of Revealed Preferences (*GARP*; see again Varian (1982)), which is the standard condition for rationality in the revealed preference literature. Similar to before, the important difference is that our rationality condition is defined for discrete choice sets and, unlike *GARP,* does not use price information.

4 Testing rationality

In this section, we present our test results for the children under study. We begin by considering pass rates for our rationality tests. Here, a particular focus will be on whether these pass rates vary depending on age. Next, to enable a better interpretation of these pass rates, we also compute the discriminatory power of the revealed preference test for our experimental design. In the current context, power stands for the probability of detecting (simulated) irrational behavior. Finally, we also report results on Afriat's cost efficiency index for our sample. As indicated in the Introduction, this measure quantifies how close observed behavior is to rational behavior, which actually allows us to measure the "quality" degree of the observed consumption decisions.

Pass rates. As mentioned before, our setup allows us to carry out the revealed preference test for each child separately. As such, we obtain 100 independent tests of rationality. Table 3 presents the results for

[13] As is clear from the text (and also from the proof in Appendix C), the following rationality condition is specific to discrete choice settings in which each choice set contains a finite number of bundles taken from one and the same budget hyperplane. We can refer to Harbaugh, Krause and Berry (2001) and Polisson and Quah (2012) for revealed tests of rationality in alternative discrete choice settings.

each age category. We learn that pass rates are generally low but increasing with age. However, even the older children in our sample behave largely irrational on average.

To put this finding into perspective, it is useful to compare the results in Table 3 with the ones obtained by Bruyneel, Cherchye, De Rock (2012). For a similar experiment (with three goods and the same prices and budgets) on undergraduate students, these authors obtained a substantially higher pass rate of 92%. As such, we can conclude that younger aged children appear considerably less rational than young adults.

At this point, we remark that this conclusion is partly at odds with the results of Harbaugh, Krause and Berry (2001). These authors focused on children of the second and sixth grade, and compared their results for these groups to the ones for undergraduate students. For the second graders they also obtained a very low pass rate (of 26%). However, the pass rate for the sixth graders was closely similar to the one for the undergraduate students (i.e. both rates were situated between 60% and 65%). One possible explanation for our different results is that we consider choice problems involving three goods, whereas Harbaugh, Krause and Berry concentrated on a simpler setting with only two goods. One may argue that adding goods makes consumption decisions more difficult, and that this effect is more pronounced for younger consumers.

	pass rate	obs
all children	0.43	100
kindergarten	0.31	39
third grade	0.48	31
sixth grade	0.53	30

Table 3: Pass rates

Power. To enable a better interpretation of the pass rates in Table 3, we also computed the discriminatory power of our rationality test. This power is defined as the probability of detecting "irrational" behavior (i.e. behavior that is not consistent with utility maximization as characterized in Definition 1). As such, this power value provides a natural benchmark for the pass rates that we discussed above: if power is situated below the rejection rates for our sample (i.e. one minus the pass rate), then we can conclude that observed behavior appears *even less* rational than (simulated) irrational behavior, which obviously provides a strong rejection of the rationality hypothesis.[14]

To simulate irrational behavior, we use the bootstrap method for panel data as described by Andreoni and Miller (2002) within a similar experimental context.[15] Essentially, this method mimics random behavior for each choice set by drawing randomly from the children's observed choices for that set (i.e. 100 choices for each of the 9 different choice sets in our setting). This gives information on the expected distribution of violations under random choice, while incorporating information on the observed choices.

More specifically, we conducted Monte Carlo-type simulations that include 10000 iterations. This obtained a power value for our test of 0.87. In other words, we compute a probability of 87% to detect irrational behavior for our experiment. This number is clearly very high, which confirms that the experiment is well-designed. Also, and importantly, it is much above the rejection rates that can be computed from Table 3. In our opinion, this provides some (albeit moderate) support in favor of the rationality hypothesis for our sample of children: even though our pass rates are rather low in absolute terms, they are reasonably high in view of the power of our test.

Afriat index. As a further investigation, we also computed Afriat's critical cost efficiency index for the choices in our experiment. To compute this index, we make use of the (implicit) prices and budgets underlying the construction of our choice sets. More precisely, for each choice observation t we compute

$$\theta_t = \frac{\min_{\mathbf{q}_s R \mathbf{q}_t} \mathbf{p}_t \mathbf{q}_s}{\mathbf{p_t} \mathbf{q}_t}.$$

[14]See Beatty and Crawford (2011) for an extensive discussion of this interpretation.

[15]We refer to Bronars (1987) and Andreoni and Harbaugh (2006) for more discussion on alternative methods to measure the discriminatory power of revealed preference tests.

In words, θ_t is obtained as the ratio of the minimal expenditure needed to obtain consistency with the revealed preference condition in Proposition 1 (i.e. $\min_{\mathbf{q}_s R \mathbf{q}_t} \mathbf{p}_t \mathbf{q}_s$) over the actual expenditure that is observed (i.e. $\mathbf{p_t q}_t$). Evidently, this ratio value equals 1 if the observed choices are rationalizable. By contrast, lower values indicate that part of the budget is wasted due to irrational choices: the child could have saved the fraction $\theta_t \mathbf{p_t q_t}$ of her/his budget while being (at least) equally well-off.

The Afriat critical cost efficiency index θ is then simply the minimum θ_t defined over all t:

$$\theta = \min\{\theta_1, ..., \theta_9\}.$$

Building further on the above explanation of θ_t, Choi, Kariv, Müller and Silverman (2011) interpret this Afriat index as a measure of the quality of the observed consumption decisions.[16]

Table 4 presents some descriptive statistics for the Afriat index. We find that the mean value of the index equals 69%, which means that children "waste" on average 31% of their budget. Similar to our results on pass rates, this can be interpreted as signalling a rather low quality of the children's decision making process, at least at the (average) level of our sample. At this point, however, it also worth remarking that there appears to be quite some heterogeneity across individual children. For example, just like for our pass rates, we again observe an age effect: children of kindergarten waste (on average) about 10% to 15% more of their budget than older children. In the next section, we provide a more in-depth analysis of (observable) characteristics impacting on the quality of children's consumption decisions.

Variable	obs	mean	std dev	min	max
all children	100	.688	.361	.11	1
kindergarten	39	.604	.382	.111	1
third grade	31	.737	.321	.11	1
sixth grade	30	.747	.363	.111	1

Table 4: Afriat's cost efficiency index

5 Explaining rationality

As a preliminary step, we consider Table 5, which provides descriptive statistics on the characteristics of both the group of rational children (i.e. children that pass our revealed preference test) and the group of irrational children (i.e. children that fail our revealed preference test). Once more, we observe an age effect. Moreover, there seem to be some differences for the personal characteristics. However, these differences do not appear to be very pronounced. Most notably, we find no significant differences when comparing mathematical or language skills for the two groups of children under consideration. Actually, this finding falls in line with the one of Harbaugh, Krause and Berry (2001), who also considered the relationship between rationality and mathematical ability, and did not detect a significant effect either.

Variable	nr rat	nr irrat	mean rat	mean irrat	sd rat	sd irrat
age**	43	57	8.605	7.614	2.77	2.814
mathematics	43	56	7.358	7.368	1.855	1.561
language	43	56	7.061	7.453	1.713	1.503
creative*	43	56	7.439	7.087	1.604	1.39
older siblings	40	53	.925	.943	.944	1.027

Table 5: Characteristics of rational and irrational children (* = significant difference at 10%; ** = significant difference at 5%)

Importantly, however, the mean values in Table 5 are unconditional in nature. For example, computing the average difference of mathematical skills for rational and irrational children does not correct for language

[16]See Afriat (1972) and Varian (1990, 1993) for more discussion on Afriat's critical cost efficiency index.

differences between these two groups of children. To allow for a conditional analysis, we will next regress our rationality results simultaneously on alternative dimensions of intelligence. This will lead to more refined insights because it effectively exploits the multidimensional nature of intelligence.[17] In fact, this also makes better use of the richness of our data on personal characteristics.

Following up on our discussion in the Section 4, we conduct two types of regression exercises: probit regressions with the rationality indicator (0 if the child is irrational and 1 if the child is rational) as dependent variable and fractional response regressions with Afriat's cost efficiency index (situated between 0 and 1) as dependent variable. In each regression, we include a kindergarten dummy and the number of older siblings as control variables. The first variable captures the age effect, for which we expect a negative sign given our previous results. Next, the use of older siblings as a control is inspired by the literature claiming that living in a family with older siblings impacts positively on the rationality of the younger children, because it makes these younger children better informed decision makers.[18]

Our core focus is then on investigating how verbal skills (language) and non-verbal skills (mathematics) define rationality of children's behavior. In particular, we address two questions. First, we want to verify whether the smarter kids are more rational. In this respect, it is worth to recall that our four intellectual characteristics are measured by comparing the children to their peers. As such, if a child achieves a high score for a particular dimension, this indicates that this child does relatively well as compared to other children of her/his age. Next, we also aim to identify the specific personal characteristics that drive rationality. Is it the case that some intellectual characteristics bear a stronger relation to rationality than others? And does the effect of alternative dimensions of intelligence move in opposite directions? A priori, because rational consumption behavior may be argued to require abstract/mathematical thinking, one may believe that mathematical ability will relate positively to rationality, while the expected effect of language may be less pronounced.

Table 6 presents our regression results. For our two dependent variables (i.e. the rationality indicator and the Afriat index) we have analyzed two regression specifications. Our main focus will be on specification 1, which (only) includes language and mathematical skills as indicators of (verbal and non-verbal) intellectual ability. As a robustness check, we also considered specification 2, which includes creativity as an additional dimension of intelligence.

If we first regard the control variables, we find that they all have the expected sign: being in the kindergarten has a negative effect on (the degree of) rationality, while having older siblings has a positive impact. However, the only significant effect is the one for age (i.e. the kindergarten dummy) in our regressions using the rationality indicator. None of the other effects is significantly different from zero.

Let us then turn to our more interesting results on the different intellectual characteristics. First, if we consider our (main) specification 1, we find that mathematical ability has a positive and significant impact on rationality. In other words, if children outperform their peers in mathematics, then there is a higher probability that they take rational decisions. Interestingly, this result is robust for both the rationality indicator and the Afriat index as dependent variables. Next, and perhaps somewhat surprisingly, we find that language has a strongly and significantly negative impact on being rational. Again, this finding holds for our two dependent variables. It appears that, on average, having better language ability goes together with less rational decision making.

An obvious question here is how we can square these results with our earlier findings (based on Table 5), where we concluded that neither mathematics nor language seemed to be related to rational behavior. The explanation for this paradox is that, as we also mentioned above, Table 5 captures unconditional effects, whereas the regression results in Table 6 define conditional effects: our regressions effectively condition on the level of verbal skills when assessing the impact of non-verbal skills, and vice versa. Thus, to identify the positive effect of mathematical ability on rationality, it turns out to be important to control for the fact that language ability has an opposite effect on rationality. Because mathematical and language skills are positively correlated (i.e. children often perform well (or badly) in both mathematics and language simultaneously), one risks to miss the significant effects when conducting an unconditional analysis. In our opinion, this may also explain the result of Harbaugh, Krause and Berry (2001) that we mentioned above. It seems that these authors found no effect of mathematical ability on the observed rationality of children's behavior because they did not correct for differences in language skills.

[17]Following the well-known Cattell-Horn-Carroll theory (Carroll, 1993), IQ must be considered as a multidimensional concept.
[18]See, for example, John (1999) for a recent survey.

To conclude, we consider the regression results for our specification 2, which includes creativity as an additional explanatory variable. Importantly, we observe that our significant effects for mathematical and language skills remain (roughly) the same as in our regressions that use specification 1. Next, the (positive) effect of creativity is significant when explaining the (binary) rationality indicator. However, the effect is not confirmed in the regression of the Afriat index. Remember that the effects of mathematical skills and language skills are stable across all four specifications. This leads us to conclude that language skills (as indicator of verbal intelligence) and mathematical skills (as indicator of non-verbal intelligence) are the more important drivers of rational consumption behavior by children. Interestingly, this coincides with the theory of Gardner (1983), who argues that there are distinct types of intelligence, and that linguistic intelligence and logical-mathematical intelligence are very important in our society.

	rationality indicator (0 or 1)		Afriat index (between 0 and 1)	
	specification 1	specification 2	specification 1	specification 2
kindergarten	-.575**	-.617**	-.657*	-.651*
	(.289)	(.298)	(.363)	(.367)
mathematics	.248*	.261*	.294*	.289*
	(.138)	(.158)	(.169)	(.174)
language	-.322**	-.499***	-.383**	-.473**
	(.14)	(.172)	(.18)	(.189)
creative		.309**		.19
		(.123)		(.124)
older siblings	.012	.02	.184	.186
	(.144)	(.145)	(.147)	(.146)
constant	.548	-.487	1.518*	.846
	(.732)	(.834)	(.837)	(.948)
obs	92	92	92	92
pseudo R^2	.0786	0.1321		

Table 6: Regression coefficients (robust standard errors between brackets) (* = significant at 10%; ** = significant at 5%; *** = significant at 1%); we use maximum likelihood estimation for our probit regressions (with the rationality indicator as dependent variable) and quasi-maximum likelihood estimation for our fractional response regressions (with the Afriat index as dependent variable)

6 Conclusion

Focusing on the consumption behavior of children, we investigated the relationship between taking rational consumption decisions and being smart. To do so, we designed an experiment involving unsophisticated discrete consumption choices (with only three commodities). In addition, we developed a revealed preference test that is specifically designed for analyzing the resulting choice data. Using teacher based assessments, we also obtained information on the children's personal characteristics, which we related to the children observed degree of rationality.

The analysis of our experimental data obtained two main conclusions. A first conclusion is that, on average, children's consumption behavior appeared to be largely irrational. In this respect, however, we also observed a clear age effect: children tend to behave more rational when growing older. More generally, we found quite some heterogeneity in rationality across children.

Our second important conclusion then pertains to relating this heterogeneity to specific child characteristics. Our particular focus here was on the effect of intellectual ability. Specifically, we considered indicators of verbal (language) and non-verbal (mathematical skills) intelligence. As a robust finding, we obtained that mathematical ability positively impacts on children's rationality, whereas language skills have a significantly negative effect. More generally, we take our results to mean that it is particularly important to acknowledge the multidimensional nature of "being smart" when relating rationality to intelligence.

We believe that an interesting avenue for follow-up research consists of explaining our results in terms of the characteristics of the decision processes that underlie the observed consumption behavior. For example, such an analysis may clarify our (perhaps somewhat surprising) result on the negative effect of language skills on the rationality of children's consumption decisions. Referring to our discussion in the Introduction, such an investigation can contribute further to a better protection of those children who appear to be particularly vulnerable consumers.

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Appendix

A. Questions posed to teachers

For each of the dimensions taken up in Table 1 we asked the following questions to the teachers (translated from Dutch):

1. "How would you position [**first name**] [**surname**] in terms of [**mathematical, language or creativity**] skills, when comparing [**him**]/[**her**] to all other pupils of similar age whom you have taught? Excellent (top 2%), Very good (top 10%), Good (top 25%), Average (top 50%), Less than average (bottom 50%), Bad (bottom 25%), Very bad (bottom 10%), Terrible (bottom 2%). (Indicate one answer, e.g. if you find that the pupil is good, but that he/she does not belong to the top 10%, indicate top 25%.)"

2. "How would you rate the [**mathematical, language or creativity**] skills of [**first name**] [**surname**], if you compare [**him**]/[**her**] to average peers? (indicate one possibility)? 1 (very weak) to 10 (very strong)"

B. Details on our experiment

Prices and choice sets

Tables 7 and 8 present the prices regimes that we used to construct our choice sets and the 9 discrete choice sets themselves.

Prices		
1 unit of grapes	1 unit of mandarins	1 unit of letter biscuits
8	4	1
8	3	2
9	3	1
1	8	4
2	8	3
1	9	3
4	1	8
3	2	8
3	1	9

Table 7: The price regimes defining the choice sets

Experimental design

The children were welcomed one at a time in a separate room. Before starting the experiment, each child was allowed to taste the grapes, mandarins and letter biscuits. They were instructed that these products were similar to the products they could choose in a next step. It was stated multiple times that each product was from the same brand and had the same quality.

We explained that they had to choose 9 successive times but that they would only receive one (randomly selected; see below) consumption bundle afterwards. Subsequently, each child was presented with the first of nine choice sets. He or she could choose one out of seven plates. Each plate displayed a consumption bundle consisting of a combination of grapes, mandarins and letter biscuits.

After a plate had been chosen by the child, we presented the next choice set, while again stating that his or her second choice was as important as the first one, and that choices were independent of each other. This process was repeated nine times. At the end of the experiment, the children were invited to draw a card with a number from one to nine. They received the corresponding consumption bundle.

C. Proof of Proposition 1

Suppose that S is rationalizable, which means that there exists a well-behaved utility function U that rationalizes S. Assume that the revealed preference condition in Proposition 1 does not hold, i.e. there exist s, t such that $\mathbf{q}_t R \mathbf{q}_s$ and $\mathbf{q}_s P_0 \mathbf{q}_t$. Then, from Definitions 1 and 2 we conclude that $U(\mathbf{q}_t) \geq U(\mathbf{q}_s)$ and $U(\mathbf{q}_s) > U(\mathbf{q}_t)$, i.e. a contradiction. We conclude that there exists a utility function U rationalizing S only if the condition in Proposition 1 is met.

Quantities		
Grapes	Mandarins	Biscuits
Choice 1		
1.5	0	0
0	3	0
0	0	12
0.5	1	4
0.75	0	6
0.75	1.5	0
0	1.5	6
Choice 2		
1.5	0	0
0	4	0
0	0	6
0.5	1.33	2
0.75	0	3
0.75	2	0
0	2	3
Choice 3		
1.33	0	0
0	4	0
0	0	12
0.44	1.33	4
0.66	0	6
0.66	2	0
0	2	6
Choice 4		
0	1.5	0
0	0	3
12	0	0
4	0.5	1
6	0.75	0
0	0.75	1.5
6	0	1.5
Choice 5		
0	1.5	0
0	0	4
6	0	0
2	0.5	1.33
3	0.75	0
0	0.75	2
3	0	2
Choice 6		
0	1.33	0
0	0	4
12	0	0
4	0.44	1.33
6	0.66	0
0	0.66	2
6	0	2
Choice 7		
0	0	1.5
3	0	0
0	12	0
1	4	0.5
0	6	0.75
1.5	0	0.75
1.5	6	0
Choice 8		
0	0	1.5
4	0	0
0	6	0
1.33	2	0.5
0	3	0.75
2	0	0.75
2	3	0
Choice 9		
0	0	1.33
4	0	0
0	12	0
1.33	4	0.44
0	6	0.66
2	0	0.66
2	6	0

Table 8: The 9 discrete choices sets