Sequential Consumer Model

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Abstract

Even if the microeconomic consumer maximization model is made discrete, the resulting complexity of optimizing over bundles of goods is not tractable for bounded rational humans. We construct a sequential consumer model based on a sequence of individual item searches and consider a condition under which the discrete sequential model approximates the discrete bundles model. We investigate how close to optimal student procedures are. First, we survey undergraduate budgeting. Progress towards optimization proceeds by an incremental adjustment process. Students' self-ratings on budget performance are related to how frequently they monitor their checking account. In a sequential model, we can consider how close to optimal is a single consumption decision conditioned on a prior correct budget appropriation. We perform an experiment with pens to show that high search costs and large numbers of alternatives imply that pen decisions are suboptimal.

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1 Introduction

The computational complexity of the traditional microeconomic consumer maximization model is transfinite except in special cases. Even if the model is made discrete, the computational complexity is exponential in the number of goods in each category, Norman et al (2001). The computational difficulty arises because the number of alternative bundles that must be considered is the number of goods in each category raised to a power equal to the number of categories. To reduce the computational complexity, consumers shop for their market baskets item-by-item.

In section 2, we discuss these issues and create a sequential model for consumer behavior. We show that the empirical condition for the sequential model to be a good approximation to the simultaneous model is that interaction effects between products can be determined at the level of multiple-alternative sets without having to consider every pair of alternatives. This eliminates the need to consider the very large number of alternative bundles, so that a solution to the new model is a good approximation to the bundles discrete model. Our goals for the new model are:

1. Investigate budgeting in this model.

2. Perform an experiment to estimate how close to optimal is human consumer behavior in a single purchase.

In section 3, we consider budgeting. We survey undergraduate students who live in apartments and budget their food consumption without a meal plan. The undergraduate students we survey are much more flexible, according to Thaler's mental accounts (1994), than graduate MBA students surveyed

by Chip and Soll (1996). Most of our students use intuitive budgeting procedures and few keep formal records. They improve their budgeting using an incremental adjustment process. Additionally, many students have a feast or famine cycle between expected influxes of income. There is a wide range of student self-ratings on how well they budget, and this self-rating relates to how frequently they monitor the flow of funds in their checking account.

In a sequential model, we can consider the optimality of an individual consumption decision conditional on having made a correct budget decision. In section 4, we perform an experiment on selecting pens to see how close to optimal student consumers are by comparing a selection decision before and after writing with the pens. We expect to observe a gap between before and after performance because a store such as OfficeMax displays several hundred pens when we consider variations in color and packaging. Students are faced with a large number of alternatives in the marketplace and given plastic packaging they can not test write with pens. The search costs incurred by writing with alternatives are high. Yet, this gap could be small since students repeatedly purchase pens. Additionally, humans have powerful set operators to deal with large numbers of alternatives, and markets are organized to facilitate the use of set operators, Norman et al (2004). We show that the students' decisions are suboptimal.

In section 5, we present our conclusions. In order to measure a consumer's deviation from optimality, economists must consider individual differences, a topic long studied by psychologists.

2 Sequential Consumer Model

Economists have studied computational complexity for at least 30 years, Norman and Jung (1977). Computational complexity is a formal measure of the difficulty in solving a problem, whereby the number of operations necessary to solve the problem are counted with respect to a growth parameter. It is important to note that the operations counted need not be arithmetic operations. They could also be psychological decision heuristics, Norman et al (2004). Computational complexity can also be assessed in an experimental setting by measuring the time required for the human neural network to process a particular type of operation, such as a binary comparison, Norman et al (2003).

The goal of this section is to produce a consumer optimization model that is computationally tractable for bounded rational consumers. Let us first consider the calculus version of the standard microeconomic consumer optimization model:

$$\max U(x_1, x_2, \ldots, x_n)$$
$$\text{subject to } p_{x_1}x_1 + p_{x_2}x_2 + \ldots + p_{x_n}x_n = I \tag{1}$$

where U is the consumer's utility function, x_j is the quantity of the jth good, p_{x_j} is the price of the jth good, and I is the consumer's income. Implicit in (1) is a time period, the length of which we will set equal to the budget period of the consumer. For most students we survey, there are two important budget periods: the month and the semester.

In the general case of the standard microeconomic consumer optimization

problem, there is no analytic solution. To obtain a solution, the problem requires an algorithm, such as a variable metric algorithm that might asymptotically converge. However, completing the algorithm requires more than a finite number of evaluations of the utility function, and it is implausible to assume that consumers can perform infinite calculations.

Given the discrete nature of modern packaging, most consumers make discrete purchases of one or more items from a category of close substitutes. For example, a college student may purchase two boxes of Cocoa Puffs from a cereal display in a grocery store. Items like gasoline, which consumers buy in continuous amounts, are made discrete by rounding off the purchase to the nearest cent. Let the sets representing the categories of goods be represented by X^i where $i = 1, 2, \ldots, n$, the elements of X^i by x^i_j where $j = 1, 2, \ldots, q$. The units of x^i_j selected by a consumer are $\mu(x^i_j) < k$, a finite bound. A discrete version of the consumer maximization problem is:

$$\max U(\mu(x^1_i), \mu(x^2_i), \ldots, \mu(x^n_i))$$

$$\text{subject to } p_{x^1_i}\mu(x^1_i) + p_{x^2_i}\mu(x^2_i) + \ldots + p_{x^n_i}\mu(x^n_i) = I \tag{2}$$

where $x^1_i \in X^1, \ldots, x^n_i \in X^n$.

While solving the consumer optimization problem now requires only a finite number of operations, it is by no means an easy problem. Let us define our primitive operations: addition, multiplication, and a binary comparison of bundles. Enumerating feasible bundles using the multiplication and addition operators is a linear process in terms of computational complexity with respect to the growth parameter, number of bundles. Determining the optimal bundle using the binary comparison operator is also a linear process with regard to the

number of feasible bundles. We are concerned about the number of bundles a consumer must consider. If the problem is made discrete, the number of operations is finite but exponential, Norman et al (2001).

To illustrate why the consumer optimization problem requires an exponential number of calculations, let us compare two types of grocery stores: a standard grocery store and a grocery store that only sells bundles of goods. To keep the example simple, let us assume that both grocery stores sell thirty categories of goods, n, with ten alternatives, m, in each category. Let us also assume, for simplicity, that the customer wants to purchase one item from each category. In a standard grocery store, each category of goods is located in a distinct aisle. The customer pushes her shopping cart through the aisles, picking one item from each category. She considers 300 alternatives, that is $10 + 10 + \ldots + 10$.

In a grocery store that only sells bundles of goods, however, the customer is presented with a line of shopping carts. Each cart contains a unique combination of thirty goods: one from each category. The number of shopping carts, q, that a bundle grocer would have to display is $q = m^n = 10^{30}$. If each cart in the line is just three feet long, a consumer would have to travel 5.68×10^{27} miles just to view all of the bundles. If it takes only 10 seconds to make a binary comparison between two bundles of 30 items, then the customer would need 1.59×10^{23} years to find her optimal bundle.

This is a worst-case scenario, of course, since we assumed that all shopping carts are budget feasible. Regardless, even if ninety-nine percent of the shopping carts were budget infeasible on average, the computational complexity of

the purchasing decision is still intractable for humans. Thus, a consumer optimization problem constructed in terms of bundles cannot accurately reflect a consumer decision process.

Consumers shop item-by-item rather than bundle-by-bundle because the number of alternatives increases linearly-rather than multiplicatively-with each category. Sellers organize their merchandise item-by-item and not bundle-by-bundle in order to minimize display space. We shall now construct a consumer model based on item-by-item search.

$$\max[U_1(\mu(x_i^1)) + U_2(\mu(x_i^2)|\mu(x_i^1)) + \ldots + U_n(\mu(x_i^n)|\mu(x_i^1), \ldots, \mu(x_i^{n-1}))]$$
$$\text{subject to } p_{x_i^1}\mu(x_i^1) + p_{x_i^2}\mu(x_i^2) + \ldots + p_{x_i^n}\mu(x_i^n) = I \tag{3}$$

For simplicity, we assume that the order the consumer decides in time is the same as the arguments in (2) and that the consumer makes one decision in each. Adding multiple decisions into each category would complicate the notation without adding insights into the problem.

Having introduced our item-by-item search model, (3), we must determine the conditions under which a solution to (3) is a good approximation for a solution to (2). The bundles model, (2), assumes that the consumer considers all possible bundles in the optimization process. We have defined U_h in (3) as $U_h(\mu(x_i^n)|\mu(x_i^1), \ldots, \mu(x_i^{h-1})$, meaning that utility in the current period is a function of previous optimal decisions. For example, if a consumer purchases a PC with a Windows operating system and subsequently searches for software, she will gain more utility from purchasing software formatted for Windows than from software suited for Mac OS X.

Thus, the structure of (3) implies that, in the item-by-item search model, fewer than all feasible bundles are considered. However, we argue that, as long as decisions regarding complements and substitutes can be resolved at the set level, it is unnecessary for consumers to consider each feasible bundle of goods. If examination of all possible bundles is not imperative, then a near optimal solution to (3) approaches a near optimal solution to (2).

So, let us determine the level at which complements and substitutes are determined in a search. Suppose a consumer wants to purchase cereal and milk to pour over the cereal. To the consumer, cereal and milk are distinct categories; they are not alternatives within the milk case or within the cereal display. In terms of utility, the variation within milk in the milk case has almost no empirical effect on the variation of cereal within the cereal display. The utility relationship between the two goods exists only to the extent that milk is needed to enjoy the cereal. Thus, the choice of cereal can be made independently of the choice of milk; put another way, decisions between complements are made at the set level of the search. Similarly, if a consumer buys a digital camera and then purchases a memory card, the memory card only affects utility derived from the camera if the card and camera are not compatible. Other differences between memory cards, such as storage capability, have no effect on utility gained from the camera itself. Therefore, decisions between complements and substitutes can be resolved at the set level in most cases, eliminating the need for consumers to consider every conceivable bundle in order to optimize. Thus, to the extent that complements and substitutes are decided at the set level, a near optimal solution to (3) approaches a near

optimal solution to (2).

3 Budgeting

In order to investigate budgeting, we conducted two surveys of undergraduates at the University of Texas. Each subject satisfied two criteria: they lived in rented apartments or houses, and they were responsible for preparing or buying meals without a prepaid meal plan. We first surveyed 49 students in the fall 2006 semester, and later surveyed 50 students in the spring 2007 semester. We paid each student seven dollars to fill in the six-page survey. Student budgeting is a particularly interesting topic, since most university students are just beginning to budget on their own. Students generally live in a dorm the first year of residence and then move into a rented apartment or house. In off-campus housing situations, students have a greater number of budgeting categories. The students in the two surveys had lived, on average, 4.2 semesters in rented housing without a meal plan. Because we improved the quality of the second survey over the first, we shall consider only the second survey responses for some questions.

In the sequential model, (3), consumers must allocate money for each purchase. The budget constraint can be written as:

$$b_1 + b_2 + \ldots + b_n = I \tag{4}$$

The budget allocation problem is determine the optimal b_j^* for $j = 1, 2, \ldots, n$ in (4) such that

$$b_j^* = p_{x^j} \mu(x_i^j)^* \tag{5}$$

As was shown in Norman et al (2001) the computational complexity of allocating I of income into the n b_i is at least a quadratic process. For example, in order to allocate just \$100 optimally into three categories in \$1 increments, the consumer would have to consider 5050 alternative allocations.

Optimal budgeting is intractable for bounded rational humans given the values of the parameters of the typical consumer problem. The computational complexity of budgeting–the difficulty of considering every possible allocation, is one possible explanation of Thaler's mental accounts (1994). Thaler's research has provided numerous examples than money is not fungible meaning that it is allocated into mental accounts that are treated differently. We have no problem with the concept that students treat money as nonfungible; when asked in survey 2, *Do you treat money you earn yourself differently from money you get from your parents? Yes 34 No 16 If "Yes", check all that apply: a. I am more frugal with my money because I earned it 22*. The responses to the questions are underlined. Also, in earlier surveys students indicated that they treated windfall gains differently from how they treated regular sources of income. We believe that the following needs reconsideration: the flexibility and extent of mental accounts. Heath and Soll (1996), in a study of MBA students, showed that these students had mental accounts for entertainment, food, and clothing that were implemented in spreadsheets. Our studies show that undergraduates use a different system that is much more flexible than those studied by Health and Soll. Furthermore, undergraduates keep fewer accounts of any type. We will show that undergraduates budget by making adjustments both within and across accounts. We theorize that budgeting is

an incremental adjustment process–a type of adaptive process, as a consumer solves (3), (4), and (5) once each budget period.

Let us start by characterizing the income sources and financial responsibilities of this group. In this group only 1 financed 100% of his college expenditures and for 17 their parents financed 100%. The underreported source of funds for the average was (1) earned 16.9%, (2) parents 58.5.4%, (3) Loan 11.2%, (4) scholarship 7.66%, and other 2.7% and the average expected debt at graduation was $8233. The budget responsibilities of students varied greatly. We are interested in the type of categories for which the student budgeters must allocate funds. In the following categories, we asked students the percentage of expenditures they paid from money in their account–regardless of the source of funds. The results for the second survey of 50 students are displayed in the table below:

Category	No.who pay all	No. who pay part	% who pay
Tuition	22	2	48
Rent	35	2	74
Auto	14	13	64
Books	29	3	64
Utilities	34	0	68
Food	33	13	98
Clothing	27	19	96
Entertainment	40	5	90
Phone	10	4	28

There is considerable variation in how students' education is financed and in student budget responsibilities. The three categories where students must budget the most are food, clothing and entertainment. We focus most of our attention on how students budget for these three categories. Our study indicates that a few students have a credit card bill sent directly to their parents,

who pay for goods under the food, clothing, and entertainment categories.

Consider the reponses from the second questionnaire. The number of responses is underlined. *Current Budgeting: Do you consider your expenses and account balance before planning for the future? [This could be done formally (e.g. in a spreadsheet) or intuitively (e.g. looking at your account balance and deciding to eat ramen for the rest of the month).]*

16. Do you budget or plan on a regular basis? Yes 37 No 13

17. Check all that apply concerning how often you budget or plan.

a. Weekly? Yes 25 No 15

b. Monthly? Yes 31 No 13

c. Each semester or summer session? Yes 29 No 13

d. When running out of money? Yes 36 No 6

18. Budget Planning: a. Do you anticipate periodic expenses, such as rent or utilities? Yes 45 No 5

b. Do you plan ahead for one-time events, such as trips? Yes 43 No 7

c. If you run low on funds, do you plan what to cut back in the future? Yes 41 No 9

20. Besides monitoring your bank accounts, monitoring your debit/credit cards, and anticipating future expenses, do you use one or more of the following methods to control your expenses?

Method A: I develop intuitive rules to control the amount of money I spend on each purchase. I do not keep records by categories of goods or by individual expenses. For example, I determine how many times a week that I can afford to eat at restaurants and the range of prices I will pay for a meal.

Method B: I budget for various categories of expense, either on paper, on a spreadsheet, or in a program like Quicken. Then I predict my expenses in each category, and if there is a discrepancy between my expense forecast and how much money I have, I plan how to bring the two in line.
Method C: Rent is fixed, utility bills are basically predictable, food varies somewhat, but I am flexible in eating out, entertainment expenses, and car expenses (if applicable). I adjust expenses intuitively.
Method D: Once a week (or other regular period), I check my account balance, determine what bills have been paid, anticipate what needs to be paid, and intuitively consider how to adjust my flexible expenditures (such as food and entertainment).
Method E: As long as the credit card bill that my parents receive this month isn't too much more than they got last month, I don't need to worry much about controlling my expenses.
Check all your methods: Method A 25, Method B 8, Method C 41, Method D 25, Method E 6. For survey 1 the response for the methods was A 17, B 3, C 40, D not asked, E 10. There were minor changes in the wording.

The question–which type of budgeting our students use, clearly indicates that a small minority of undergraduates use formal budgeting procedures like a spreadsheet. Most undergraduates use an intuitive and flexible procedure. Even though a majority of our students budget on a regular basis, their budgeting consists of monitoring current status and then considering future expenses. For many students, budgeting consists of making rules at the aggregate level, such as how many times a week to eat out.

One aspect of budgeting is monitoring accounts to keep track of the flow of funds. Of these 99 students that keep track, 22 know their bank balance at all times, i.e. by balancing their checkbooks after each transaction. Using the internet and voice recognition systems, students can easily monitor their accounts online or by phone. All 99 members of this group have checking accounts, 90 have debit cards, 50 have credit cards where the bill comes to them and 48 have credit cards where the bill comes to their parents. How frequently they monitor account is shown in the table below:

Frequency checked in days	Checking account	Bills	Credit Card
Left blank	2	4	11
1	20	17	19
2	22	13	8
3	9	7	4
4	2	1	1
5	7	9	9
6	0	0	1
7	14	17	17
10	3	5	1
14	4	1	2
15	2	3	5
20	0	1	1
30	13	20	29
60	1	0	0
90	0	1	0

As can be seen by the table above, 74 out of the 99 students check their checking account at least once a week. These 74 students check which bills have been paid and their credit card balances less frequently than they track their checking accounts. For most of our students, one aspect of budgeting is keeping track of the flow of funds.

Students learn to budget by making adjustments. The response to the

following questions is indicated by underlining,

- *23. Since Sep '06, how many adjustments to your spending patterns or income? None 1 Few 37 Several 10 Many 2.*

- *24. In order to reduce overall expenses to income I cut back on overall expenses? Yes 35 No 10*

- *25. In order to balance expenses and income, I increased my income Yes 23 No 26.*

- *26. Did you cut expenses in one category in order to increase expenses in another? (For example, cutting food costs to free up money for entertainment.) Yes 28 No 19.*

- *28. I have increased or plan to increase expenses in one or more categories because I have or will have more money to spend (includes budget estimate too high). Yes 13 No 35.*

- *29. If at the end of the month (or other budget period) you tend to run out of money and cut back to make it to the next period, what categories do you cut?" 39 indicated they cut categories.*

In questions 24, 26, 28, and 29 they were to indicate the categories they adjusted. The number of subjects who adjusted these categories is shown in the following table for the indicated questions:

Category	Q24 Cut	Q26 Cut	Q26 Increase	Q28 Increase	Q29 Cut
Tuition	0	0	0	1	0
Rent	1	0	2	1	0
Auto	2	1	4	2	0
Textbooks	0	2	4	0	1
Utilities	1	1	5	1	1
Food	23	13	0	1	16
Clothing	9	4	3	1	5
Entertainment	21	11	12	6	23
Cell phone	1	0	0	0	0
Other	1	0	1	1	0

Now let us look at how students adjusted their income, food, and entertainment expenses. The responses to the following question are indicated by underlining, *39. Have you gotten more money than you expected to in Sep '06? Yes 21 No 29. If Yes, check all that are applicable: Got a job 9, Worked longer hours 8, Pay raise 4, Obtained more money from parents 8, Sold possession on eBay 4 Other 4.* Of the 32 students in survey 2 that made food expenditure adjustments: (1) 29 learned to cook, (2) 26 ate out less frequently, (3) 23 selected less expensive items from the menu, and (4) 23 bought less expensive groceries. Much of the adjustment in reducing food expenses consisted of increasing labor input to reduce cash flow. Another example of where a student could use more labor to reduce expenses is buying textbooks online instead of from the UT bookstore. 31 students indicated they planned to buy textbooks online in the future. Of the 42 students adjusting entertainment expenses, 8 would date less, whereas 10 would date more; 18 would go out less and 11 more; 24 would go to less expensive events and 3 to more expensive events. Going to the movies is an example where students have a menu of choices, such as going to a movie theater, $8, renting a DVD, $4, or checking out a DVD from the library, $0. The adjustment process involves adjusting income,

labor input, and choices. Besides permanent budget adjustment, many students make adjustments throughout their budget cycle, as indicated in survey 1: 24 out of the 49 students indicated that their budgeting was a feast and famine cycle, where they spent more than average the first two weeks and then had to cut back the last week.

The response to the following two questions is underlined, *41. How did you make the adjustments? Check all that apply:*

a. Intuitively adjusting spending in various categories without making an explicit budget. 33

b. Made a budget in my head to adjust expenses. 31

c. Made a budget on paper to adjust expenses. 13

d. Made a computer budget to adjust expenses. 10

42. How long did it take you to adjust your budget? Week 15 Month 16 Semester 5 Still adjusting 14.

We conclude that humans simplify the budget process using a hierarchical decision structure. For example, in making a decision to eat a meal a student can first choose between several alternatives such as cooking or eating out. If she decides to eat out, then the second decision is which restaurant. Upon arrival at the restaurant, she checks the menu in order to select a specific alternative. Such a hierarchical structure vastly decreases the number of specific alternatives that she must consider. It also gives her a mechanism to create simple rules to control expenditures, such as a limit on how many times to eat out per week, the determination of a set of restaurants within budget limits, and a limit on how much to spend in a restaurant. Thus, with simple rules,

expenditures can be controlled; using adjustments, a student can search for the best definition of rules and tradeoffs between categories of expenditures. In the budget survey, over 40% indicated they budget by creating rules.

How well do these students budget? One way to answer this question is to ask students to self-rate their budgeting skills. *21. Based purely on your subjective opinion and given the amount of time you spend, how well do you budget? Key: Use a 0–10 range, where 0 indicates that you have no grasp of your expenses and 10 indicates that you always know what's going on and allocate money wisely among alternatives. Your self-rating* _____ . The average response was 6.74. The distribution of self-ratings is shown in the table below:

Self-rating value	1	2	3	4	5	6	7	8	9	10
Number selecting above	0	2	1	0	6	8	16	5	10	1

We performed a regression to see if the self-rating was related to how frequently students monitored their checking account.

$$Y_i = a + bX_i + \epsilon_i \tag{6}$$

where Y_i is the i^{th} student's self-rating score, $X_i = \ln Z_i$ and Z_i is the frequency with which the student monitors his checking account and ϵ_i is an independent random variable with 0 mean. The regression results are shown in the following table:

Coefficient	Value	Standard Error	t Stat	P-value
a	7.81	0.40	19.61	0.00
b	-1.38	0.47	-2.93	0.01

The regression shows that the more frequently students monitor their checking accounts, the higher their budgeting skill self-rating. The R^2 for the regression is 0.16, which indicates that there are also many other factors explaining self-rating.

4 How Close to Optimal

In Norman et al (2001) we showed that solving the 2-stage consumer problem was intractable for a human even with a polynomial assist from a digital computer; therefore, we consider it a waste of time to ask whether consumers determine the mathematical optimum of (3). Instead, we believe researchers should investigate the performance of humans in solving (3). For this purpose the great advantage of a sequential model is that if we stipulate that the consumer has a good solution to the budget problem we can focus on the performance in making a single purchase.

The first step is choosing a type of purchase to investigate. For this purpose we have considered the purchase of pens, a product with which students have had experience since elementary school and generally purchase frequently. To focus the question, we need to ask whether performance converges to optimal for a type of purchase a consumer makes repeatedly. If the introduction of new alternatives into the marketplace is low, the search costs should decline as the consumer uses accumulated knowledge to make the search more efficient. The model (3) does not include search costs so we would expect a gap in performance for one-time purchases where the search costs are significant. Is this gap small for repeated purchase items such as pens?

Let us start by considering the market for pens. We shall only consider the market for pens costing less than $2. Pens can have fountain, ball point, roller ball, gel, and porous combinations of points and tips. There are numerous brands including Bic, Foray, PaperMate, Sanford, Pental, Pilot, Tul, Uniball, and Zebra. While most pens sold have black ink, many other colors

are also sold. Pen tips include medium, fine, or extra fine. Pens are sold in various packages such as single, two or three, 6, 12, 24, 36, or 48. There are a large number of alternatives in the marketplace. For example, the UT Co-op displays over 240 various pen alternatives and the local OfficeMax over 400.

Now let us consider the factors that affect optimal performance in selecting a preferred pen within the budget constraint. From our previous research with pens, Norman et al (2003) and Norman et al (2003a) we know that for most consumers the smoothness with which a pen writes is an important factor in evaluating a pen. Given modern packaging, most pens are sold in plastic packages that do not allow the consumer to write with them. Consequently, students can learn how a particular pen writes by using a friend's pen or buying one to test it. Such sequential testing is expensive and is governed by Tversky and Kahneman's (1982) prospect function that people avoid downside risks. This implies that as students find pens they like, they are less and less likely to test pens by buying one. The various manufacturers of pens introduce several new pens each year and with R&D the quality of pens is improving. This means that there is no steady state optimal decision. These factors suggest that there is likely to be a gap between actual and optimal performance in selecting pens.

Because humans have powerful decision heuristics and market organization facilitates such heuristics, the gap between actual and optimal performance could be small. The efficiency of these heuristics was analyzed in Norman et al (2004). If a consumer used a linear heuristic such as a binary comparison to process 400 pen packages at a store like OfficeMax, it would take her over an

hour if she took 10 seconds to read the information on the packages to make her decision. Humans have set operators that are much more efficient. For example, if she knows from previous experience that she likes Pilot brand gel pens, she can reduce the 400 pens to a considerably smaller number. Because stores organize the pens by type and brand, she can make this set operation with a single observation. Thus, if consumers develop a preference over attributes such as point type, point size, color, brand, and price range, they have narrowed the market to a small number of alternatives that they could test. These factors suggest that the gap between actual and optimal performance could be small.

Now let us consider the basic idea behind our experiment. If subjects' choices were optimal, then when faced with a large selection of pens, they should be able to pick the preferred pen without writing with it. We will have subjects write with pens after their first selection to see if they prefer another pen after writing with a set of similar pens. Then we will have students give us their subjective evaluation of preferred pen. Finally, they must buy a pen with the $2 that they brought with them to see if their behavior is consistent. In order to test students' market responses, we performed an experiment in which students selected a pen before and after writing with them. They were scheduled with the following email message: "Please come by my office BRB2.122 (across the parking lot from Gregory Gym) at noon Monday for the pen experiment. Bring $2 and the pen you use most often. You will net $8+ plus a pen you like. Experiment will take 15-20 minutes. Please respond by 7pm Sunday as to whether you can come."

Prior to selecting students for the experiment we queried them to determine what type of pen they generally used. One group of students generally used inexpensive stick ball point pens. From this group we selected 20 students for the experiment. Of the pens they brought to the experiment, 19 were some type of Bic ball point pen and one was a PaperMate ball point pen. On the questionnaire before the experiment, 7 indicated they never buy pens. Instead they obtain them from business giveaways, parents, or friend and 13 indicated that they buy pens that cost no more than $0.25 each, 14 of the first group were prepared to pay on average $.93 to obtain a pen that wrote better than a stick ball point pen

Group One: Now let us consider the experiment for the first group. Subjects sat at desk upon which were 13 stick ball point pens. The instructions for the experiment are shown below. The responses are underlined in the instructions or are shown later in a table.

III. Pen test

Background: There are 13 pens on the desk. All of these pens are inexpensive ballpoint pens. Pens are numbered 1 through 13. There is a price in red ink. When you write the name of the pen selected indicate by the number for brevity.

a. There are 13 pens on the table, about how many have you written with ___ [Average = 5.75]

b. Choose your preferred pen of the 13 without writing. Pen number is _____

c. Now write with each of the 13 pens and list the ones by number that write better than first pen selected. Separate with a comma. _____

d. After writing which pen is the preferred pen when you consider the price (Remember: The price is written in red) _____ [Same pen 6 and different pen 14]

e. The price of the pen selected before writing is _____ and the price of the pen after writing is _____. Now taking the price of the more expensive pen as a reference what is the value of the other pen to you in terms of price. _____ For example if the more expensive pen is the before writing pen, is the value of the of the after writing pen to you greater? If the more expensive pen is the after writing pen, is the value of the of the before writing pen less? Write your value.

The proctor will make you an offer on the price of the preferred pen before writing and the preferred pen after writing. You must buy one or the other pens.

e. Offer: First pen _____ Second pen_____ Result_____

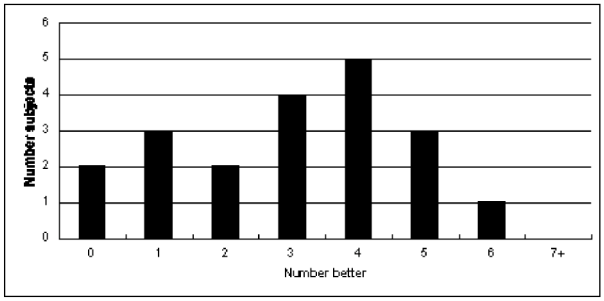
These pens and their unit price were;

No.	Pen	cost	Q b.	Q c	Q d
1	Office Depot Stick Pens 1.0mm	0.08	0	4	2
2	PaperMate Grip XL Grip Medium	0.19	2	3	0
3	Bic Round Stic Grip Fine	0.19	6	6	1
4	PaperMate Write Bros Medium	0.11	0	3	0
5	PaperMate Eagle Med 1.2	0.11	1	2	1
6	Bic Round Stic Grip Medium 1.2	0.18	5	7	3
7	OfficeMax BallPointPens Med	0.08	0	5	0
8	WalMart Office Ballpoint Med	0.05	0	1	1
9	Bic Round Stic M	0.08	2	1	2
10	Target Stick Pens Med	0.05	0	2	1
11	Bic Cristal Easy Glide Med	0.13	1	9	1
12	Target Stick Pens BBR 50	0.08	2	10	9
13	Target SuperTips	0.10	1	1	0

Now let us explain the results. In the table and discussion below Q a., Q b., Q c., Q d. and Q e. refer to questions a. through e. of the instructions

above. Of the 13 pens displayed on the table, the average number of pens with which a subject had previously written was 5.75, less than one half. The column under Q b in the table lists the number of times subjects selected that pen as their first selection. On average when writing with all the pens a subject found three pens that wrote better than the first pen. The column Q c indicates the number of times the various pens wrote better. As might be expected the correlation between the number of pens a subject had previously written with, Q a, and the number of pens that wrote better than the first selection, Q c is negative, -0.4. In response to Q d 15 subjects selected a pen out of the group that wrote better. In response to Q e. for the 14 subjects who bought a cheaper pen revised that value of that pen upward by an average of 242%. The one subject who bought a more expensive pen revised his estimate of the value of the first pen downward by 6%. We gave the 15 subjects who indicated a second pen better than the first a price for the first and second selected pens to see if their buying decision was consistent with their stated preferences. Of these 15 subjects, 13 made a choice consistent with the prices offered. They had to pay for the pen with money they had brought with them to the experiment and not house money. It is therefore not totally surprising that about 3/4s choose a different pen after we lowered the search costs of writing with pens.

If we simply look at the number of pens that write better we can say that on average the first choice was fourth best and in the upper third. The distribution is shown in the graph below:



Looking at the graph 5 subjects found four pens wrote better than the one they first selected.

Group Two: In the preliminary query, another group of students indicated that they generally used a better pen than an inexpensive stick ball point pen. We selected 20 students from this group who brought the following pens to the experiment: 7 were Pilot G2s, 4 were Bic Atlantises, 3 were Pilot Precise V5s, 1 was a PaperMate USA, Pilot EasyTouch, Bic round Stic, Pentel Energel, Uniball, and Pentel RSVP. Only 1 of the second group indicated they never buy pens and only 4 bought inexpensive stick ball point pens. All 20 of the this group were prepared to pay on average more than $1.39 to obtain such a pen that wrote better than a stick ball point pen.

Now let us consider the second group who regularly use better pens than inexpensive stick ball point pens. The changes in the instructions from the first inexpensive ball point group were that 13 was replaced with 50. Question c was modified, *c. Now write with each pen in same group as best preferred pen and list the ones by number that write better than first pen selected. Separate with a comma.* _____ There was also an additional question, *f. Write with the 2 pens from each of other groups that are marked with the circled x on*

green or pink squares: How many better than best after writing pen above ____.

The fifty pens were divided into four groups: ball point, roller ball, gel, and porous. The porous pens were (1) PaperMate Liquid Expresso med, (2) Pilot Razor Point, (3) Le Pen marvy, (4) PaperMate Flair Medium, (5) Sharpie Ultra Fine, (6) Sharpie Fine, (7) Bic Markit Ultra Fine, (8) Bic Markit Fine and the pens in the other three categories are listed in the tables below. The average response to Q a. was 10.6, which indicates that on average the subjects had only written with about 1/5th of the pens on the desk. In response to Q b. no subject selected a porous pen, 5 subjects selected a ball point pen, 7 subjects selected a roller ball pen, and 8 selected a gel pen. We have constructed three separate tables for ball point, roller ball, and gel pens below.

Ball Point Pens: 5 subjects

No.	Pen	cost	Q b.	Q c	Q d
1	PaperMate Xtend	\$0.79	0	0	0
2	Pilot EAsyTouch	\$0.62	1	0	0
3	Bic Body Action	\$1.90	0	0	0
4	PaperMate Cap pen Med	\$0.70	0	0	0
5	Foray Satin Flow BallPoint Pens	\$0.45	0	0	0
6	Pental RSVP	\$0.47	2	0	0
7	Zebra Z Grip Medium	\$0.44	0	3	2
8	Bic Smoothie BallPen	\$1.50	0	1	
9	Bic Atlantis	\$0.52	1	3	1
10	Bic Pro +	\$1.25	1	1	1
11	PaperMate Click Pen 1.4 Bold	\$0.87	0	2	1
12	Tol Ball Point	\$1.08	0	0	0

Roller Ball Pens: 7 subjects

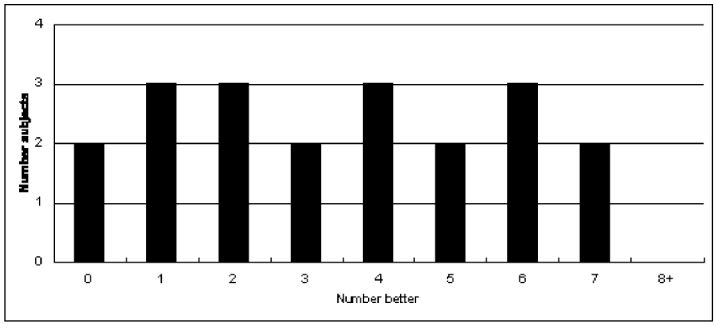
No.	Pen	cost	Q b.	Q c	Q d
1	Pilot Vball Grip Fine	$ 1.75	0	3	3
2	Uniball Rollerball Grip Fine	$ 1.57	1	3	0
3	Pilot Vball Grip extra fine	$ 1.54	0	4	2
4	Pentel Rolling Writer Med	$ 1.29	0	0	0
5	Pilot Precise V7 Rolling Fine	$ 1.48	0	3	0
6	Pilot Precise V5	$ 1.33	3	0	0
7	Uniball Rollerball Fine 0.7	$ 1.60	1	2	0
8	Uniball Deluxe Fine 0.7	$ 1.90	1	3	0
9	Pilot Precise Grip Extra Fine	$ 1.55	1	4	0
10	Bic Z4 Roller	$ 1.25	0	2	0
11	Corner Office Roller ball	$ 0.75	0	1	0
12	Sakura Gelly Roll	$ 1.04	0	2	2
13	Uniball Vision Micro	$ 1.95	0	0	0
14	Pilot Precise Grip Bold	$ 1.00	0	2	0

Gel Pens: 8 subjects

No.	Pen	cost	Q b.	Q c	Q d
1	Pilot G2 07 Gel	$1.09	2	3	1
2	Pilot G2 05 Extra Fine	$1.29	1	1	1
3	Inc Classic Gels	$0.47	0	2	1
4	Zebra Orbitz	$0.81	0	1	0
5	Pentel RSVP gel	$1.76	0	3	0
6	Tul Gel Medium	$1.50	0	6	1
7	Tul Gel Fine	$1.50	0	1	1
8	Zebra GR8	$1.20	1	3	2
9	Uniball Signo Roller Gel	$1.55	0	0	0
10	Foray Gel	$1.36	0	1	0
11	Pilot Precise Gel	$1.33	0	1	0
12	Uniball Gel RT Micro	$1.57	1	0	0
13	OfficeMax Gel Pens	$0.72	0	4	1
14	Bic ReAction Get	$1.56	3	2	0
15	Target Gel Pens	$0.67	0	1	0
16	Zebra SARASA Gel Retractable	$1.13	0	1	0

Now let us analyze the results. Again Q a. - Q e. refer to the questions in the instructions. Of the 50 pens on the table the average number that a subject had previously written was 10.6. On average, this group found 3.45 pens that wrote better than their first selection. For this group there is a positive correlation between the number of pens the subjects had previously written

with and the number they decided wrote better than their first selection. After writing with the pens in the selected group, 4 out of the 20 selected the same pen the second time and 16 selected a different pen. In response to Q e. the average absolute change in valuation from the actual price to the subjective value was 38.8%. Given prices for the first and second selected pens, 2 of the 15 for which we had data were inconsistent with their selection. It is therefore not totally surprising that about 3/4s choose a different pen after we lowered the search costs of writing with pens. Again, if we simply look at the number of pens that write better, we can say that on average for the first group, the initial choice was on average fourth best and in the upper third. The second group produced the following results. For the five subjects who initially chose a ball point pen, their initial choice was on average in the upper 1/4 of the ball point pens. For the seven subjects who initially chose a roller ball pen, their initial choice was on average in the upper 36% of the roller ball pens. For the eight subjects who initially chose a gel pen, their initial choice was on average in the upper 30% of the pens. The distribution of the number of pens that wrote better was:



To interpret the graph note that 3 subjects thought that 1 pen wrote better than the first pen they selected and a different 3 subjects thought that 6 pens

wrote better than the first one they selected.

Because testing alternative pens is expensive our subjects had tested about half of the inexpensive ball point pen market and about 20% of the less than $2.00 pen market, it is not totally surprising that the performance of most is suboptimal.

5 Conclusion

Our paper lays out a sequential approach to consumer theory. How close an approximation solving this model is to solving the bundles optimization model depends on whether compliments and substitutes can be handled at the set level eliminating the need to consider every possible combination in optimization.

With a sequential model the focus shifts from do or do not consumers optimize, but rather how close do they come. The minute you ask this question you must consider individual differences, a topic long studied in psychology but never in economics. If everyone optimizes there can be no individual differences.

Our budget surveys indicate that students make incremental adjustsments to improve their budgeting. Their self-awareness of how well they budget is related to how frequently they monitor their checking account. Our experiment suggests that their is a gap between optimal and actual performance. This gap exists even in an inexpensive item that is purchased frequently because of the arrival rate of new technology and the high search costs of writing with alternative pens. In both cases that is a wide variation in individual

performance.

This paper is a start and hopefully it has generated your interest to perform research in this line of study.

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