Decisions and strategies in a sequential search experiment

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Abstract

The strategy method is becoming an important tool in experimental methodology. This study examines how well this method works in an individual decision experiment. Subjects are faced with a sequential search problem. After extensive practice in solving the problem and formulating strategies, they play 20 periods for money. In each period the subjects first make decisions by hand, after that their strategy operates on the same sequence of bids. In each period, only one of the results is paid out (randomly determined). After each period, subjects can change their strategy. This method makes a direct comparison between strategies and decisions possible. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The strategy method is becoming a more and more popular tool in experimental economics (Selten, Mitzkewitz & Uhlich, 1997; Brandts & Schram, 1996; Sonnemans, 1998a; Mitzkewitz & Nagel, 1993; Keser, 1992; see also the classic work of Axelrod, 1984). Subjects are asked to formulate a complete strategy, that is, a description of all their actions in all possible states of the world. After a state of the world occurs (as a result of actions by others or a random mechanism), the action prescribed by the strategy is carried out. The subjects are paid according to the performance of the strategy.

In everyday life, an individual may also use an explicit strategy to instruct an agent (e.g. a stockbroker). In these instances, strategies are interesting in their own right. The strategy method may also be useful in other situations because of two main advantages: (1) it is a cheap way to gather many data and (2) the researcher may get a better idea of the reasoning behind the behavior of the subject. Furthermore, subjects have an incentive to report honestly what they think is the best strategy because they are paid according to the performance of the strategy they submit. This is an important advantage of the strategy method over questionnaires. However, a very important question is whether these strategies indeed correctly describe the decisions the subjects would make when actually confronted with a state of the world. A difference between strategies and decisions can be caused by the inability of some subjects to formulate their behavior in an admissible form of the strategy. For example, in most strategy-method experiments subjects are not allowed to include random mechanisms in their strategy, although they might normally act more or less impulsively. Differences can also be caused by subjects making mistakes if they have to make many repeated decisions (as is the case in many experiments), and they may avoid these mistakes in their strategy. Furthermore, some subjects see a strategy as a kind of commitment. They formulate how they think they should act, although they know that normally they would sometimes deviate from this strategy (Sonnemans, 1998a).

Before economic experimentalists can really trust the strategy method, we need an evaluation of the method. To make a start, the present study compares decisions and strategies in a relatively simple individual decision-making environment.

One possible experimental design to compare strategies with decisions is to let subjects make decisions in the first part of the experiment and formulate
strategies in the second part. For each subject the researcher can compare the decisions in the first part with the actions the strategy would choose in the same states of the world. This design was used in Sonnemans (1998a). Although this method may give some idea about the usefulness of the strategy method, it has the disadvantage that the subject may have learnt and changed his or her strategy during the experiment.

In this study, an attempt is made to establish the correspondence between strategies and decisions of subjects in a different way. In a sequential search experiment, subjects first play some practice periods in which they make decisions and practice formulating strategies. Then they start the first period by formulating a strategy. In each period, subjects first make decisions, after which their strategy operates on the same state of the world (sequence of bids). In each period only one of the results is paid out (randomly determined). After each period, subjects can change their strategies. This method makes a direct comparison between strategies and decisions possible.

The two central questions of this study are:
1. Is the strategy method a valid tool in the specific environment of individual search experiments?
2. Can we observe systematic differences between the decisions and the strategies?

Section 2 is a description of the design of the study and Section 3 contains the results. Section 4 lists the conclusions.

2. Design

In two sessions 31 subjects participated. Subjects were undergraduates in various disciplines, mainly economics, chemistry and psychology. Nobody had participated in previous search experiments. The subjects earned an average of 27.3 guilders in approximately 1 hour. The experiment was computerized. The computer program was made by the author in VISPRO-REXX for an OS/2 environment and is available from him.

2.1. The search problem

Subjects in the experiments are confronted with the following search problem. They receive an ‘article’ which they have to sell to the computer. The computer starts with an initial bid. The subject can accept this bid, or ask for another bid. The number of bids is unlimited and at any time the subject
can decide to sell for the highest bid so far. Each bid costs 10 cents and is
drawn from a discrete uniform distribution $[1; 500]$. All bids are stochastically
independent. There is a fixed cost per period of 250 cents.

A risk neutral decision maker will stop searching if the marginal cost of an
additional search action ($= 10$ cents) exceeds its expected marginal benefit:

$$0.002 \sum_{j=H+1}^{500} (j - H) = 0.001 \times (500 - H) \times (501 - H),$$

with $H$ the highest bid so far.

This means that search will continue until a bid greater than 400 cents is
drawn (the reservation price). The expected earnings are 150.5 cents with a
standard deviation of 53 cents.

2.2. Strategies

Subjects are asked to formulate strategies. For practical reasons the
strategies have a specific format. This format was also used in another study
(Sonnemans, 1998a) and is based upon a pilot study in which 70 high school
students made decisions by hand and afterwards filled in a questionnaire in
which they described their strategy. All these strategies can be formulated in
the format used in the present study. In the Sonnemans (1998a) study only 2
of 36 subjects wanted to submit a strategy which did not fit the format. This
means that the possibilities offered to the subjects are not very restrictive. The
strategy is a stopping criterion that consists of one stopping condition, or a
combination of more conditions. The stopping conditions have the form:

I want to stop:

A. If the last bid is greater than or equal to: ...
B. If the highest bid is greater than or equal to: ...
C. If the number of bids is greater than or equal to: ...
D. If my earnings are greater than or equal to: ...
E. If ... bids in a row are smaller than the highest bid so far.

The subject fills in numbers for the stopping condition(s) he or she wants to
use, and formulates the stopping criterion “X” if only stopping condition X
is to be used, or a logical combination of stopping conditions e.g. “X or Y”,
or “X and Y”, or “(X or Y) and Z”. After the subject has formulated a
strategy, the program reformulates the stopping condition in words to check
whether the strategy is really what the subject wants it to be (e.g. “stop if the
last bid is greater or equal to 425, or the number of bids is greater or equal to
If this is not what the subject meant it to be, she can change her strategy. The program also warns subjects who formulate a strategy which may never stop (e.g. the strategy “stop if my earnings are greater than or equal to 200” either stops after one of the first five bids or never).

Of course it would have been possible to use a larger permitted strategy space. Besides the fact that this would cause a practical problem (it would have been more difficult to explain and more difficult to program), the main problem would be that if subjects have the opportunity to construct very complicated strategies, they may conclude that complicated strategies are required to perform well (while in fact the optimal strategy is a very simple one). Non-optimal behavior by subjects may then be caused by a suggestive environment. Note that nevertheless the number of possible strategies is enormous (one can make more than 100 different combinations of criteria and many millions of different strategies can be constructed filling in different numbers).

2.3. Procedure

Subjects received instructions on paper. A translation of these instructions is included in the extended version of this paper (Sonnemans, 1998b), available upon request. First the search problem was explained. Then they answered three questions to check their understanding. The experimenter checked the answers to these questions and, if necessary, answered questions. Subjects then practised 20 periods in which they had to decide (by hand) whether they wanted another bid. After this, they received instructions how to formulate a strategy. The experimenter showed them how to input their strategy. They practised another 20 periods. They could change their strategy after each period. If there was some time left, they could also practise with the computer screen as used in the real experiment. After everybody finished the instructions and had a chance to practise with the computer screens, the experiment was started. Subjects could not earn money in the practising periods.

The experiment lasted 20 periods. Before the first period, subjects formulated a strategy. In each period subjects first made decisions (requested as many bids as they liked), and then their strategy operated on the same sequence of bids. In each period only one of the results was paid out (randomly determined). Subjects could change their strategy after each period.

This set-up ensures that subjects always have an incentive to make (what they think is) the best decision. If they think that it is better to act different
from their strategy, they should decide to do so, because there is a 50% probability that the result of their decision and not the result of their strategy is paid.

3. Results

We will first take a short look at the kind of strategies subjects employed and the optimality of the subjects’ decisions before we turn to the main focus of this paper: the correspondence between the strategies and the decisions.

3.1. Kinds of strategies used

The subjects had much opportunity to practice, and when they started the 20 experimental periods, they seemed quite confident about their strategy. Of the total number of 31 subjects, 20 subjects did not change their strategy at all in these periods, seven subjects did never change the form of the strategy but changed the numbers within the strategy (two subjects did this once, four subjects twice and one subject three times), and only four subjects did change the form of their strategy (three subjects changed once and one subject changed three times). Most subjects may have felt that there was not much room for improvement of their strategies. Not one subject indicated that he or she wanted to use a strategy which was impossible to formulate within the restrictions of the experiment.

Only 8% of the strategies are reservation price strategies, and none is exactly optimal. The number of bids is included in 68% of the strategies and the earnings are included in 74%. The order of bids is included in 16% of the strategies (these percentages do not add to 100% because subjects can use combinations of conditions). ¹

3.2. Optimality of decisions and strategies

How well did the subjects perform? Their earnings are 138.7 cents on average for decisions and 135.0 cents for strategies per period, this is 92.2% and 89.7% respectively of the earnings an optimal risk neutral strategy would earn on average (150.5 cents). The average number of bids is 4.93 (decisions)

¹ See Sonnemans (1998b) for a complete overview of the strategies used by the subjects.
and 4.94 (strategy), while the risk neutral optimal strategy would request five bids on average (see also Table 4). Stopping is optimal in 66% (decisions by hand) and 69% (strategies) of the cases, and strategies appear to stop more often early than late.

In the set-up of this experiment, subjects can revert to an earlier bid (the earnings equal the highest bid minus the costs, not the last bid minus the costs). However, the risk neutral optimal strategy will never revert to an earlier bid. In the experiment, reversions to an earlier bid occurred in 16.5% (decisions by hand) and 15.8% (strategies) of the periods.

The results of this experiment are generally in line with the findings in other studies (Schotter & Braunstein, 1981; Hey, 1987; Cox & Oaxaca, 1989, 1992; Kogut, 1990; Sonnemans, 1998a,b): search is highly efficient (in terms of earnings) and there is some tendency to recall. In many studies, subjects tend to request too few bids (compared with the risk neutral optimal strategy), e.g. Cox and Oaxaca (1989), Schotter and Braunstein (1981). In this study, the average number of bids is close to the average optimal number of bids; this may be caused by the extensive opportunity for practice.

3.3. Decisions and strategies compared

The most interesting question is how well the strategies correspond with the decisions. During one period several decisions have to be made (after each bid the decision is to stop or not), the number of decisions depending on the number of bids. The decisions by hand equal the decisions by the strategy in 91.8% of the cases.

Another way to look at this is to count the number of periods in which the strategy and the decisions by hand behave exactly the same (they stop after exactly the same bid). This happens in 402 periods of the 620 (65%). When strategies and decisions do not coincide, the strategies-earnings are on average 10 cents less than the decision-earnings (Table 1).

The next question is whether the differences between decisions and strategies are systematic, or only caused by small mistakes (noise). During the first 4 bids, the decisions by hand equal the decisions by the strategy in 94.2% of the cases, this decreases to 89.6% for the fifth bid and 85.1% after that. Apparently strategies and decisions differ more often in periods with a ‘bad sequence’ in which the first 4 or 5 bids are low. Table 2 displays the incidence of reversion in the periods where behavior and decisions by hand did or did not coincide. If the strategy and the decisions correspond, reversion to an earlier bid is rare (less than 3%). In periods in which strategy and decisions do
not coincide, reversion is very common: 42% of the decisions by hand and 40% of the strategies, and only in 30% no reversion occurred in both strategy and decision by hand. This suggests that disagreement between decisions and strategy is not only noise. Apparently many subjects wanted to stop (and revert to an earlier bid) after receiving many bids, but did not have a clear strategy when to stop exactly.

3.4. Individual differences

Six subjects formulated strategies which corresponded with all their decisions in at least 18 of the 20 periods (in all periods for two subjects). Six other subjects did extremely bad; in less than 50% of the periods, decisions and strategies coincided exactly. As described above, decisions and strategies disagree most often when subjects are confronted with a sequence of relatively low bids. Some subjects may have encountered more often these ‘bad’ sequences, which may partly explain the individual differences. To test this, I compare the number of periods in which decisions and strategies corre-

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<th>Table 1</th>
<th>Average earnings and number of bids when the strategy and the decision do and do not correspond</th>
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<td>Average earnings</td>
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<td>decision (cent)</td>
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<tr>
<td>Decision equals strategy</td>
<td>159.8</td>
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<td>Decision differs from strategy</td>
<td>99.7</td>
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<tr>
<td>Total</td>
<td>138.7</td>
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<th>Table 2</th>
<th>Reversion to an earlier bid by strategy and decision by hand, in the periods where strategy and decisions by hand do or do not coincide</th>
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<tr>
<td></td>
<td>Decision equals strategy</td>
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<td></td>
<td>Strategy no reversion</td>
</tr>
<tr>
<td>Decision no reversion</td>
<td>391</td>
</tr>
<tr>
<td>Decision reversion</td>
<td>0</td>
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<tr>
<td>Total</td>
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sponded with a binomial (0.65,20) distribution,\(^2\) using a Kolmogorov–Smirnov goodness of fit test. The test yields a 2-tailed \(p\) of 0.056, showing that substantial differences between subjects cannot completely be explained by some subjects being more (un)lucky with their series of bids than others. The conclusion is that the strategy method seems to work better for some subjects than for others.

4. Discussion and conclusion

In this study, the validity of the strategy method is examined in a specific environment: an individual sequential search experiment. The design enables to compare decisions and strategies.

The strategies described 92% of the decisions by hand correctly. Because in a period a subject has to make many decisions (depending upon the number of bids), only in 65% of the periods the decisions by hand coincided completely with the strategy. It is a matter of personal taste how satisfied we are (or should be) with the performance of the strategy method: we have to balance the pros (a very rich dataset and a good idea of the reasoning by the subjects) and the cons (an incomplete correspondence of strategies and decisions by hand). Personally I think that for many research purposes these numbers are quite satisfactory.

The periods in which the decisions by hand do not coincide completely with the strategy are generally the ‘bad sequences’ in which the first 4 or 5 bids are low. For a rational risk-neutral subject the number of bids received should not matter (the costs of these bids are sunk-costs), but for most subjects the number of bids does matter (the number of bids are included in 68% of the strategies). These subjects want to revert to an earlier bid if it takes too long before a high bid appears. When their strategy reverts to an earlier bid, only in 11.2% of the cases the decision reverts after the same bid (and in 26.5% after another bid), and if the decision reverts, the strategy inverts in only 10.8% of the cases after the same bid (and in 25.5% after another bid) (see Table 2). Reversion is rare in cases when strategy and decision correspond. Apparently some subjects want to revert to an earlier bid in some situations, but they do not have a clear idea in which situations

\(^2\) Remember that in 65% of all periods decision and strategy correspond.
exactly, or they are not able to formulate their strategy correctly in this respect.

Some individual differences are observed. It is likely that the strategy method will work better in some populations of subjects (e.g. subjects with some practice in abstract reasoning) than in others.

There are two arguments why the strategy method would work better in an individual decision experiment than in an experiment with social interaction. (1) In some game-experiments subjects have to give their strategy for each possible role, before they get to know what their role is (e.g. divider or responder in an ultimatum game). This forces the subject to look at the situation from different viewpoints which may influence behavior (see Güth & Tietz, 1990; Güth, Ockenfels & Wendel, 1997). (2) In games in extensive form or repeated games, emotions may play a more important role in decision making than in formulating strategies. For example, a subject may become angry because other player(s) made an unfair or stupid decision, and he or she may act impulsively. While formulating a strategy the same subject has to think about his/her action when this unfair situation occurs, but emotions will be of less importance because it is unlikely that the subject will become angry merely by the thought that the other player(s) may act unjustly.

These two possible problems of the strategy method in experiments with social interaction do not occur in individual decision-making experiments. However, I do not think that the present study is a relatively easy test for the strategy method. In this sequential search experiment the set of possible states of the world for which a strategy has to be formulated is infinite \( \{ (x_1, \ldots, x_n), n \in N, x_i \in [1; 100] \} \) with \( x_i \) a bid from the computer, while in most other experiments the set of states of the world is limited. In the present study, subjects could not list all possible states of the world and indicate what they would do in each specific state. They had to use (a combination of) stopping conditions. This is, of course, a more abstract and probably for most subjects a more difficult procedure (however, note that the optimal strategy for a risk-neutral decision maker is very simple).

In a recent study by Offerman, Potters and Verbon (1999) strategies and decisions are compared in a game environment, using a similar method as the present study. They use a strategy method to study an overlapping generations game (the so-called pension game). The game is played by a sequence of players. The payoff of a player depends upon his own decision and the decision of the next player. Each player chooses between a cooperative and a non-cooperative choice. The cooperative choice is costly but benefits the previous player. In the experiment, subjects formulated a strategy (a decision
for any possible position in the sequence and any possible history of choices by earlier players) before playing the game once. The game was then replayed with the strategies instead of the decisions. A random device determined whether the result of the strategy or the decision was paid. In the baseline experiment 28 of the 31 decisions were consistent with the submitted strategy (90.3%).

The strategy method has some important advantages and is becoming popular. What we need now are methodological studies about how the strategies correspond with decisions. This study focused on a specific individual decision-making environment while the recent study by Offerman et al. (1999) focused on a specific extensive form game. We now need similar studies on the use of the strategy method in other environments.

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