Experimental Economics and the Theory of Decision Making under Risk and Uncertainty

John D. Hey[1]

Universities of Bari and York

Abstract

Following a brief review of the main experimental work into the economics of risk and uncertainty, both static and dynamic, this paper reports the results of an experiment testing one of the key assumptions of the theory of dynamic economic behaviour – that people have a plan and implement it. Using a unique design which enables the plan (if one exists) to be revealed by the first move, the experiment was implemented via the Internet on a subset of the University of Tilburg's ongoing family expenditure survey panel. The advantages of using such a set of subjects for the experiment are twofold: the demographic characteristics of the set are known and therefore demographic inferences can be made; the representativeness of the set is known and therefore inferences about populations can be made. The results suggest that at least 36% of the subjects had behaviour inconsistent with the hypothesis under test: that people formulate plans and then implement them. Interestingly demographic variables are unable to explain the consistency or inconsistency of individuals. One conclusion is that subjects simply make errors. An alternative conclusion, consistent with previous experimental research, is that people are unable to predict their own future decisions. The implications for dynamic theory (particularly relating to savings and pensions decisions) are important.

1. Introduction[2]

The title of this paper is the title of the talk that I gave in Strasbourg. Clearly a paper that gave full justice to everything covered in this title would be more than a paper. Instead I concentrate on a small but very important subset of the material covered by the title – specifically concerning the issue of how people take dynamic decisions under risk. However, in analysing this topic, I find it useful to draw on some results from other areas within the field covered by the title of this paper. I will therefore begin with some general introductory remarks concerning the field as a whole.

2. The theory of decision making under risk and uncertainty

[1] I would like to acknowledge financial assistance from the European Commission through the TMR grant "Savings and Pensions". I would particularly like to thank Marcel Das and the whole team at the University of Tilburg which implemented the experiment on a subset of the CentER panel; they put in an enormous amount of work in adapting my experiment for implementation on the panel and I am very grateful to them.

[2] This paper originates in a paper given as the 2001 Risk Economics Lecture at the 28th Seminar of the European Group of Risk and Insurance Economics in Strasbourg in September 2001. I would like to thank the Geneva Association and particularly Christian Gollier, for the invitation to present this lecture. I would also like to thank my discussant Marc Willinger who provided interesting new insight into the assumptions that I was implicitly adopting. His comments forced me to explicitly strengthen the assumptions and hence explicitly weaken the conclusions. Moreover his comments confirmed my suspicions that some assumptions are necessary to implement the approach advocated in this paper, and that the assumptions necessary are by no means vacuous.

Economics has a well-organised story of decision making under risk and uncertainty. It adopts a two-way classification which we can summarise in the following table:

1. Static decision making under risk	2. Static decision making under uncertainty
3. Dynamic decision making under risk	4. Dynamic decision making under uncertainty

The two distinctions used in economics are (a) risk *versus* uncertainty[3] and (b) static *versus* dynamic. These give us the four classifications of the table above.

The first category, "Static decision making under risk", is enormous, both as far as theory is concerned and also as far as experimental studies of those theories are concerned. The second category, "Static decision making under uncertainty", is less intensively developed, but there is a lot of theoretical work and a modest amount of experimental work. The third category, "Dynamic decision making under risk", is receiving increasing theoretical attention and also experimentalists are moving into the field; this is the field on which I will concentrate in this paper. The fourth category, "Dynamic decision making under uncertainty", is virtually unexplored, both by theorists and experimentalists.

As I remark above, I intend to concentrate on recent work in the third category, but I want to draw on some key results from the first and second categories. I will therefore begin with an extremely superficial overview[4] of these first two categories, focussing particular attention on findings that I want to use later.

The economic theory of static decision making under risk is extremely well-developed. Its flagship is undoubtedly Expected Utility theory, a powerful, normatively-appealing, and extensively applied theory which has numerous important applications, not least in the area of insurance. At the same

[3] I do not want to get bogged down in difficult definitions at this stage. I hope it suffices that what I mean by risk is a situation in which probabilities are taken as given by everyone, whereas in a situation of uncertainty there is no general agreement about what the probabilities are or even whether they exist.
[4] A rather dated survey can be found in Hey (1997).

time, and as a consequence, it has been tested extensively with experimental methods, and, at times, has been found wanting. As a consequence of these perceived shortcomings of the theory, there have been numerous theoretical developments, which have themselves stimulated further experimental work.

As a theory of individual decision making, the usual experimental way of testing Expected Utility theory and its various rivals is through the direct or indirect testing of the axioms of the theories. For example the Independence Axiom of Expected Utility theory, which states that a risky prospect *A* is preferred to some other risky prospect *B* if and only if the mixture[5] *[A, C; p]* is preferred to the mixture *[B, C; p]* for *all p* and *C*, can be very simply tested by offering subjects a choice between *A* and *B* and then offering them a choice between *[A, C; p]* and *[B, C; p]*. If we have in place some appropriate incentive mechanism, then we can see if actual choice (that is, actual preference[6]) is compatible with the axiom. If it is then we gain confidence in the axiom; if not then we increasingly suspect the axiom.

A simple example of this procedure is the following. Subjects in an experimental setting are given two pairwise choice problems, as follows:

Problem 1: a choice between *£30 for sure* and the prospect *[£40, £0; 0.8]*.
Problem 2: a choice between the prospect *[£30, £0; 0.25]* and the prospect *[£40, £0; 0.2]*.

The incentive mechanism[7] is the following: after the subject has stated his or her preferred choice in each of the two problems, then one of the two problems is chosen at random, and the preferred choice on that problem played out for real and the subject paid accordingly.

This is a simple test of the Independence Axiom. If a subject obeys the Axiom, then, if he or she chooses *£30 for sure* (*[£40, £0; 0.8]*) in Problem 1, then he or she should choose *[£30, £0; 0.25]* (*[£40, £0; 0.2]*) in Problem 2; if he or she does not, then his or her behaviour violates the Independence Axiom. In practice the experimentalist usually asks this pair of questions to a whole set of subjects and then does a statistical test of whether the proportion of the subjects choosing *£30*

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[5] Where by the notation *[A, B; p]* I denote a risky prospect which yields *A* with probability *p* and *B* with probability *(1-p)*. In the case of a 50-50 gamble between *A* and *B* I shall use the abbreviated notation *[A,B]*.
[6] The "appropriate incentive mechanism" is one that ensures that choice and preference coincide.
[7] This mechanism works if the subject considers each problem independently of the other. If he or she does not then the 'Holt objection' comes into force. I shall ignore this objection, since taking it into account complicates the exposition without changing the force of the conclusion.

for sure in Problem 1 is significantly different from the proportion of the subjects choosing *[£30, £0; 0.25]* in Problem 2.

It is instructive to ask why the test is done in this particular fashion, and particularly to ask what is the stochastic story lying behind (and hence justifying) this test. Clearly there must be some randomness – otherwise the statistical test has no basis. But where is it? Is it across subjects or within subjects? If the *same* set of subjects has been asked the two questions[8], then the randomness must be within subjects – for if it was across subjects, then one can test for violations subject by subject.

What does this mean – this randomness *within* subjects? Simply that there is some randomness in the answers of each subject. As I have described it elsewhere, Hey (1995) there is some noise or 'error' in subjects' responses.

This is abundantly clear. One way of checking for this is to ask the same question more than once. It is now generally accepted that, on the type of questions usually asked in experimental studies of decision making under risk, that if asked the same question twice, up to 30% of subjects give different answers on the two separate occasions. Very clear evidence is contained in an experiment which I recently conducted, Hey (forthcoming), in which subjects were asked the same 100 pairwise choice questions on 5 different occasions (spread over a period of over a week). The table below gives some idea of the variability in subjects' responses.

	1 to 2	**2 to 3**	**3 to 4**	**4 to 5**	**Sum**	**Over all 5**
minimum	3	1	0	0	4	3
maximum	29	22	25	23	91	48

The row labelled 'minimum' is the number of different answers given by the subject with the smallest number of such different answers; the row labelled 'maximum' is the number of different answers given by the subject with the largest number of such different answers. The column headed '1 to 2' compares the first time the subject did the experiment with the second time; and so on. The column headed 'sum' is just the sum of these. The column headed 'over all 5' relates to the number of pairwise choice problems with different answers given sometime in the five repetitions.

[8] Some early experimental tests used different subjects for the two Problems, but this practice is now very rarely followed.

The ‘minimum’ row shows that there was at least one subject who became consistent by the third repetition and stayed consistent thereafter. However, the ‘maximum’ row shows that there were subjects who remained very inconsistent right to the end. Subjects were generally distributed reasonably evenly between these two extremes.

It is clear from this that there is a lot of ‘noise’ in subjects’ responses. We might wonder whether this is error of some kind or whether there is some uncertainty in subjects’ preferences, but we can certainly conclude that there is error or noise or variability, of a not negligible magnitude, in the responses of subjects in the kinds of experiments that are typically carried out to test economic theories of decision making under risk. As economists we should not be surprised by this, given that it takes time and effort to answer questions in an experiment, and the rewards from the experiment may not justify the expenditure of a large amount of time and effort. This is the first message that I want to take from previous experimental work: *that there is ‘noise’ in subjects’ responses*.

I also want to take a message from the experimental work done in the second field, that of static decision making under *uncertainty*. Everyone knows the classic ‘experiment’ in this field – resulting in the Ellsberg Paradox. There are two urns: a risky urn which contains 50 white balls and 50 black balls; and an ambiguous (or uncertain) urn which contains 100 balls, each of which may be either white or black. Subjects have to choose an urn and a colour. Then one ball is drawn at random out of the chosen urn and if it is of the chosen colour then the subject is given a prize; if it is not of the chosen colour then the subject is given nothing. The ‘paradox’[9] is that subjects usually choose the risky rather than the ambiguous urn.

This description hides some serious problems concerned with the implementation of the experiment. When Ellsberg described the ambiguous urn he was a little vague about how actually it is composed. In an experiment you have to tell subjects. If you try to avoid this, then you have a problem in that subjects may ask you – and then you have to answer. Given the sophistication of present-day experiments and present-day subjects, you can not rely on getting away with a vague answer (and you should not try to – as it is crucial that subjects understand clearly every aspect of an experiment). Subjects in an experiment are, even if only implicitly, entering into some kind of contract with you. Either them, or the Ethics Committee of the University, may well want to check that what you are saying is true. More importantly, you as experimentalist want to make sure that what you tell them is true[10]. So you have to work out what you are going to do in implementing the uncertain urn.

This is not an easy task. In practice, there are a number of ways of implementing the uncertain urn. As might be expected, most of them correspond to some theory of economic behaviour under uncertainty. For example, one way involves *probabilities of probabilities*: here subjects are told, for example, that the experimenter will start with 101 cloakroom tickets numbered from 0 to 100; one of these tickets will be picked at random and the number of white balls in the urn will be the number on the ticket. Note that this procedure can be implemented at the end of the experiment in full view of the subjects – so no deception is, or needs to be, involved. Moreover it corresponds to a particular interpretation of uncertainty – as probabilities of probabilities – on which theories[11] have been built.

Some may argue that this is not true uncertainty – it is not the uncertainty that Ellsberg wanted. Ellsberg wanted something that was truly unknown. But what other method can we use? Some experimentalists have conditioned the outcome of the experiment on events which, it is hoped, the subjects know absolutely nothing about – for example the value of the Malaysian stock market at 9.30 am on Monday the 17th of September 2001. The experimenter presents two possibilities: one that this index is above 19436.4 and the other that this index is below 19436.4. These are the white ball and the black ball in the uncertain urn. Is this what Ellsberg wanted? Is this true uncertainty?

I must admit I do not know. Notwithstanding the fact that you may have a Malaysian amongst your subjects, I find it worrying that differing subjects *may* have different perceptions about these two outcomes. So you, as the experimenter, have lost a bit of control over the experiment. I also find it of concern that subjects may worry about why you have chosen that particular example. They can work it out that you know what the value of the index is likely to be – you obviously know something about the index. Notwithstanding the fact that the subject can choose the colour of the ball, I would feel that this implementation would make the subjects suspicious of what is going on – and hence make them have prejudices against the uncertain urn. You could try and guard against this by getting a subject chosen at random to form the uncertain urn – but this could again arouse

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[9] In itself this really is not a paradox as the subject could be indifferent, but different formulations and experimental tests seem to show that there is actually a strong strict preference for the risky urn.

[10] I do not want to enter into a debate here on the ethics or otherwise of deception as an experimental tool. Suffice it to say that I do not approve of the use of deception. Some of my views are expressed in Hey (1998).

[11] Theories which necessarily drop the Reduction of Compound Lotteries Axiom, for otherwise the 'probabilities of probabilities' would reduce back to 'probability' through the use of this Axiom.

suspicions. If you have suspicious subjects you have lost some control. In the UK you could condition on something more obvious to the subjects – such as the weather the day after the experiment – but here subjects will bring differing prior knowledge to the experiment: you, as experimenter, again have lost some control over what is going on.

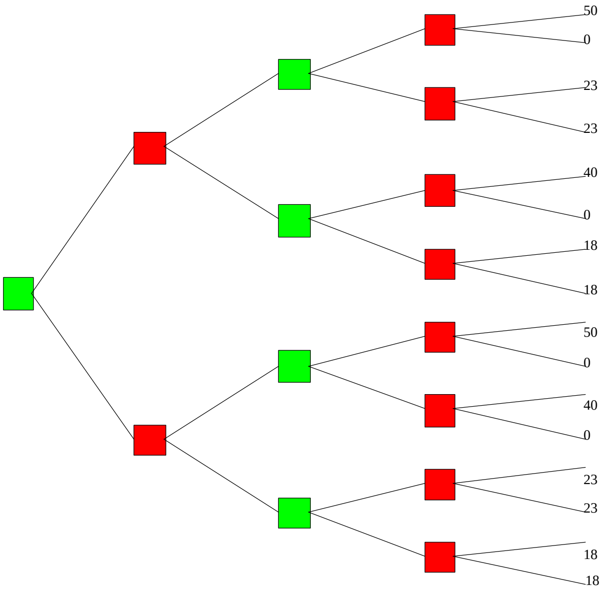
Actually there is one element of the above formulation of the experiment that is of concern: the fact that subjects can choose the colour of the ball on which they bet. The reason for this is to allay any suspicion that the subjects may have that the experimenter has fixed something in some way. Of course there are other ways round this problem – like first asking them how much they would pay to bet on different colours from different urns – but this complicates the design somewhat. Note also that if the subjects are reasonably sophisticated and they are given the option to choose the colour on which they bet, then they can choose the colour through randomisation themselves – in which case you are carrying out some kind of joint test of their probabilistic assessments of the two urns and their probabilistic sophistication. This may be a different kind of test than that envisaged by Ellsberg.

The key point that I want to make is that you should have an experimental design in which everything is clear to the subjects and that there is no deception. In particular, you should not tell them one thing and then do another. This, as we shall see, has implications for the design of the experiment that I want to present and discuss.

3. Dynamic decision making under risk

This is the field that I want to spend most of my time discussing. It is a field where there is a reasonable amount of theoretical work and a modest amount of experimental work. In my opinion, it is a field wide open to advances in both theory and experiments. While theorists have done some work in this area, I think that economists are really rather ignorant of the way the dynamic decisions under risk are taken in practice. I come to this conclusion as there seem to be a number of important 'anomalies' that economists are unable to explain. These include: 'excessive' saving amongst the elderly; the proliferation of a large number of committed savings schemes with no obvious advantages; and the fact that consumption seems to be 'excessively' sensitive to income. My own feeling is that many of these anomalies are explicable through the inability or unwillingness of people to plan – and it is to explore this potential explanation that the present paper is devoted.

I represent a dynamic decision problem under risk in the following tree form – where square boxes represent either chance nodes or choice nodes. In the figure that follows the first and third (set of) nodes (reading from the left to the right) are choice nodes; and the second and the fourth (set of) nodes are chance nodes. The tree is particularly simple in that at each choice node there are just 2 choices and at each chance node there are just 2 possibilities. To make things simple I assume that at all chance nodes each of the two possibilities are equally likely – that is, there is a probability ½ that Nature moves Up and a probability ½that Nature moves Down. The decision maker starts at the first choice node at the left of the tree and has to work his or her way through the tree, finally arriving at one of the terminal nodes, with each of which is associated a payoff. So the decision maker must choose Up or Down at the first choice node; then Nature moves, choosing Up or Down with equal probability. Then the decision maker has to make a second choice – to move Up or Down at the second choice node. Then Nature makes a final move – Up or Down with equal probability. Then the decision maker gets the associated payoff.

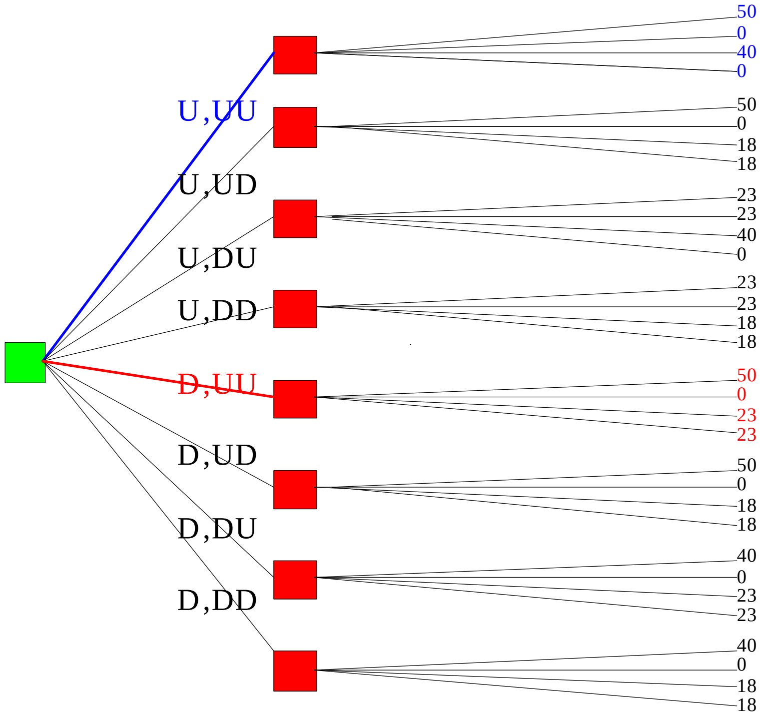


What does economic theory say about the way that the decision maker should tackle this problem? There are essentially three approaches, which can be called:

1. The strategy approach.
2. Backward induction with reduction.
3. Backward induction with certainty equivalents.

The second and third of these are very similar – so I will describe just one of them. The first approach involves converting the problem from a dynamic choice problem into the choice of a *strategy*. A strategy is a set of decisions as to what to do at each choice node that one might reach.

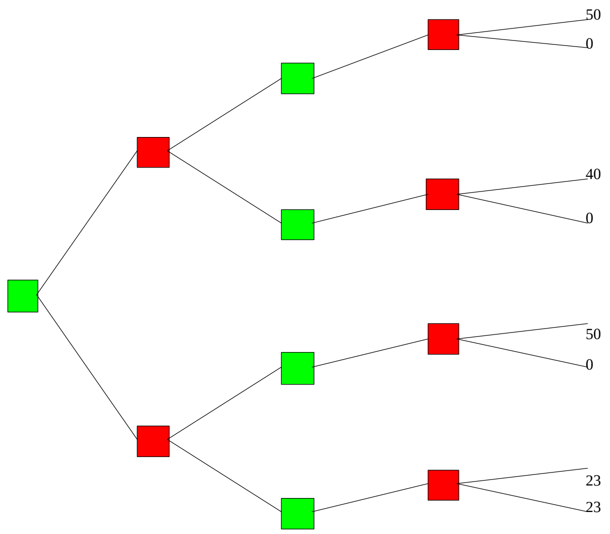
One possible strategy is to choose Up at the first choice node and then play Down at the second if Nature moves Up and to play Up at the second if Nature moves Down. This strategy leads to possible payoffs of 23, 23 , 40 or 0 – all with equal probability ¼. There are 8 possible strategies in total (which are (U;UU), (U;UD), (U;DU), (U;DD), (D;UU), (D;UD), (D,DU); (D,DD) using an obvious notation). With each of these there are four possible equally likely payoffs and we get the following set of possible strategies.



Note that the original dynamic problem has now been converted into a static problem. The decision maker can now evaluate the various strategies using whatever static decision rule he or she has. This could be Expected Utility or whatever. For a decision maker who is risk-neutral the best strategy can be seen to be (D;UU) – so a risk-neutral agent chooses Down at the first node and then Up at the second, irrespective of whatever Nature moves.

The other two methods of solving the dynamic choice problem involve the use of *backward induction* – either with reduction or with certainty equivalents. With backward induction *with reduction* the decision maker works backward through the tree, deciding what to do at each of the final choice nodes, eliminating the branches of the tree that he or she then knows he or she will not follow, reducing the tree by the Reduction of Compound Lotteries Axiom, and hence reducing it to a static choice problem, and thus solving the choice at the first node. If we once again take a risk-neutral agent, then it is clear from the above tree that the optimal move at each of the four second choice nodes is Up. If we eliminate the Down at each second decision node we get the tree below. This is a static choice problem and the best decision for a risk-neutral person at the first choice node is clearly Down. So the risk-neutral agent chooses Down at the first node and then Up at the second node (irrespective of what Nature moves).

I note that in this example, with a risk-neutral agent, we get the same decisions whichever method we use the solve the dynamic choice problem. This will in fact always be the case if the static preferences of the decision maker are Expected Utility; if the preferences are *not* Expected Utility then different approaches to solving the dynamic choice problem *may* lead to different decisions.



This latter is an interesting issue but not the one that I want to explore. This latter is the fact that each of the approaches described involves the use of a *plan*: the decision maker, in choosing what to do at the first choice node, anticipates what he or she will do at the second choice node. This idea – that people *plan* when tackling decision problems – is the one that I want to examine in this paper.

I note that the idea - that people plan - is fundamental to the way economists think about dynamic decision problems. It is almost equivalent to saying that people are rational: people, in deciding what to do now, think of what they will do in the future. More fundamentally, given that the payoffs in this tree are not received until the end of the tree is reached, economists would ask how a decision could be taken unless some thought is given to what the decision maker will do in the future? If the decision maker does not plan, how can he or she rationally make a decision? It is this that I want to examine in this paper.

The basic point is thus this: the theories that economists use all assume that people plan; how can we check first whether this is true and secondly whether people actually implement the plan that they have made[12].

There is a fundamental methodological problem in detecting whether people have a plan and whether they implement it: in itself *a plan is unobservable*. At this point we could get a little entangled with semantics ("a plan is an intention, something that one plans or intends to do", which seems to suggest that it is not a plan in the sense of the theory) but I would prefer not to do. I would prefer to continue using the word 'plan' in the sense of the theories that I have described above: it is a statement of what the decision maker *will do*. But how do we observe it? More importantly, how do we provide appropriate incentives in an experiment for a subject to honestly report a plan – assuming, of course, that they have one.

And this final point raises another methodological concern, which is crucial if we want to see if people do have plans: if we use the word 'plan' in an experiment, if we ask subjects what they are planning to do, then we raise in their minds the idea that they ought to have a plan. Just mentioning the word 'plan' in the instructions could well change their behaviour. We do not want to change their behaviour; we just want to observe that behaviour.

What other people have suggested is that the way round the first of the problems is to ask subjects what they are planning to do – *and then force them to do it*. But this changes the nature of the decision problem – you are effectively forcing subjects to pre-commit and hence use the strategy approach to solving the problem. This is a bit counter-productive if you actually want to observe which approach they are using. OK – it tells you how they solve a strategy problem – but it does not tell you how they solve a dynamic choice problem.

Other experimentalists are even more ingenious – they tell their subjects, when choosing at the first node, that they have to pre-commit to a choice at the second node, *but when it comes to the second choice node they tell them that they can change their minds*. This seems objectionable on a number of grounds, not least that it involves deception (which strikes me as pretty serious) but also that it tells you nothing about what you wanted to know ("whether people make a plan and then implement it") but tells you what people do if they are forced to pre-commit but then are (unexpectedly – at least one hopes that it is unexpectedly unless your subject pool has been polluted

[12] Obviously in the theories people implement the plan that they have made: if they knew that they would not

by previous deception) allowed to change their minds. This may be interesting – but it is not what we set out to do.

Other experimentalists are still more ingenious – they tell their subjects that they have to pre-commit but that there is a chance[13] that they will be allowed to change their minds. The problem with this is that it changes the decision tree that the subjects are tackling – it introduces a further chance node in the tree. There is no guarantee that the solution to the new tree has any relationship with the solution to the original tree. The same is true of a device I tried myself, in an experiment in which subjects were told, when they were taking the decision at the first choice node, that they had to state a decision at the second choice node but that they could change it – at a cost – when they came to take the second decision[14].

All these methods seem to have difficulties. Instead I have been led to thinking about designing an experiment which *reveals* the plans or intentions that people have. Just as we can get people to reveal their preferences, we might be able to get people to reveal their intentions. The idea is this: that, in a two-stage decision problem, the decision at the first node *reveals* what they intend to choose at the second node. This is not as easy as it appears. One does not want a problem so simple that everyone does the same thing: one wants some people to choose Up at the first node and some people to choose Down at the first node. So we do not want Up or Down to dominate[15] at the first node. Similarly we do not want Up or Down to dominate at the second node.

Consider the following design. I want to separate the subjects into two groups – the first group choosing Up at the first node and the second group choosing Down at the first node. We then want to be able to predict the behaviour of the subjects at the second choice node, conditional on what they did at the first.

This is the way I implemented the idea. I build the experiment around two basic gambles[16] – *A: [900, 50]* and *B: 400 for sure.* The prospect *A* is attractive to risk-lovers, risk-neutral agents and those who are only moderately risk-averse. The prospect *B* is attractive to those who are more than

implement them then they would form a different plan and perhaps come to different decisions.

[13] Some stochastic device will be invoked just before the second choice node to determine whether they can change their minds or not.

[14] As it happened, only one subject (out of some 175) changed his or her mind!

[15] In the sense of first-order stochastic dominance – so that one choice is better for everyone irrespective of their preference function.

[16] Recall the notation: *[A,B]* indicates a 50-50 gamble between *A* and *B*.

a little risk-averse. I do not know *ex ante* which prospect any subject will prefer. I now construct further gambles from these basic two:

A^+ *= [950, 100]* B^+ *= 450*

A^- *= [850, 0]* B^- *= 350*

Note how these are constructed: A^+ and B^+ are both 50 better than *A* and *B* respectively; A^- and B^- are both 50 worse than *A* and *B* respectively. I make the following assumptions:

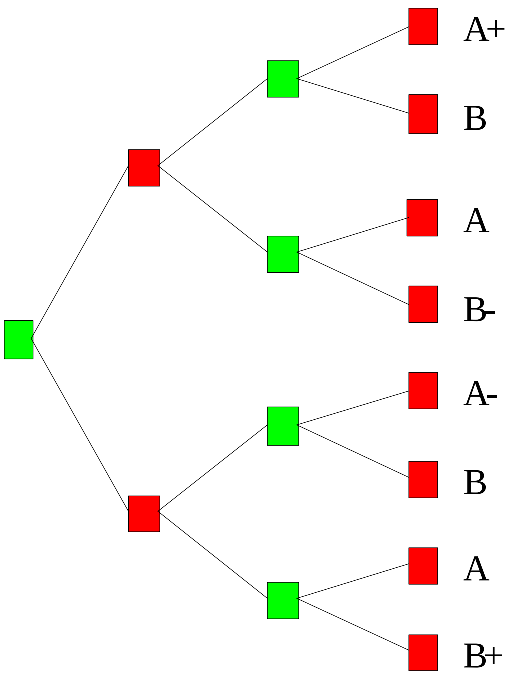
Assumption 1:

A^+ is preferred to B^+ ***if and only if*** *A is preferred to B* ***if and only if*** *A^- is preferred to B^-*

Assumption 2:

If C is preferred to E and D is preferred to F then [C,D] is preferred to [E,F]

Assumption 1 seems pretty harmless. Assumption 2 is less harmless; it is implied by the Independence Axiom or by separability, but Independence or separability are not required for it. However, both are assumptions, though it seems to me that some such assumptions need to be made if we are going to implement this *revealed intentions* approach. Consider now the following tree. It is designed in such a way that if a subject chooses Up at the first choice node then he or she should choose Up at the second; if a subject chooses Down at the first then he or she should choose Down at the second. That is, of course, if the subject has a plan and implements it.



Why do I assert this? I have a long proof (available in the Appendix), but the following intuition may be better. Suppose an individual is more than a little risk-averse and prefers *B* to *A*. This subject should choose Down at the first node and then play Down at the second. Why? Because choosing Down at the first will give him or her either *B* or B^+ for sure while choosing Up at the first gives him or her only *B* or B^- for sure. Having chosen Down at the first, then this individual will have a choice either between A^- or *B* or a choice between *A* and B^+: the second of these (Down) is always preferred to the first.

Another intuitive proof is by showing that someone who choose Up at the first node and then Down at the second is doing something a bit odd. Note that by choosing Down at the second after choosing Up at the first gives the subject either *B* or B^-. But if the individual wanted a certainty rather than a risk all along then he or she could have got a better certainty by choosing Down in the first place and then down again, hence getting either *B* or B^+. So *ex post* behaviour is a bit strange if it implies outcomes of either *B* or B^- instead of outcomes of *B* or B^+. A similar argument shows that choosing Down at the first node and then Up at the second is also odd behaviour.

The bottom line of all this is that the first move *reveals the plan* (or intention) of the subject, assuming, of course, that the subject does indeed plan. Specifically, a choice of Up at the first node reveals the intention to choose Up at the second node, and a choice of Down at the first node reveals the intention to choose Down at the second. For those subjects who do indeed choose Up after Up or who choose Down after Down, their behaviour is *not inconsistent*[17] with the hypothesis that they have a plan and implement it. For those subjects who choose Up after choosing Down or who choose Down after choosing Up, their behaviour is inconsistent with the hypothesis that they have a plan and implement it. We now describe an implementation of this experiment.

4. An experimental investigation of dynamic decision making under risk

The experiment described above was implemented on a subset of the CentER panel. This panel, maintained by CentER at the University of Tilburg, is an ongoing family expenditure panel of Dutch households which CentER has been monitoring for some years. CentER has a wealth of survey information on this panel, both of a demographic nature and of a financial nature. The great virtue of this panel is that panel members are equipped with a computer connected to CentER. As a

[17] Note, of course, that this does not *prove* that they have a plan and implement it.

consequence, questionnaires – and more importantly experiments – can be down-loaded on to panel member's computers.

This is what happened with my experiment. On two weekends in April and May 2001 CentER sent out an invitation to participate in the experiment. Along with the invitation was a full set of instructions which enabled potential participants to see what was required. There was also a practice facility – which enabled potential participants to try out the experiment as much as they wanted. Obviously if they did decide to participate they could do the experiment only once - and had to say in advance when they were ready to participate. A total of 1029 subjects completed the experiment. They were visually presented with the tree – almost as it appears in this paper[18]. When they were ready to participate they were asked to choose Up or Down at the first node. They were then asked to confirm their decision. Then the half of the tree that they had rejected went grey. For roughly half the subjects (Treatment 1) they were then told Nature's move at the first chance node; for the other half (Treatment 2) they had to wait 24 hours before being informed of Nature's move. All the subjects had to wait 24 hours before making their choice at the second choice node. Nature then made its second move and the subjects were informed of their payoff. They were then paid the payoff.

Note that all subjects had to wait 24 hours between taking the first decision and taking the second. There were two reasons for this: the first was simply to give them some time to think – so they did not rush into the second decision; the second, and perhaps the most important, was to separate in their minds the two decisions – so that they did not think of them as one decision. If they had so thought then they could be considered as having been forced to think of a plan. I deliberately did not want them to be forced to plan their decisions.

I have 1029 subjects. I have information on certain of their demographic and financial characteristics. In particular I have information on: their position in the household; their sex 1=male, 2=female); their age (in years); their education (the higher the number the higher the education); their activity (essentially whether they were working or not); the number of members in the household; the number of children in the household; whether they had a partner living with them; the gross income of the household; the net income of the household; the gross income of the subject; and the net income of the subject. There are some clearly dubious responses to the income

[18] The experiment can be visited at http://cdata4.kub.nl/experiment, but note that this is not in the final form in which it was actually implemented.

questions (so the figures that I present should be treated with some caution), but most of the data seems accurate.

Of the 1029 subjects, 622 chose Up at the first node and 407 chose Down. It may be of interest to know the characteristics of these two groups. Recall that the relatively risk-averse subjects should choose Up at the first node.

Decisions at first node	Sex	Age	Education	Number of children	Net subject income
Up	1.46	43.4	2.77	0.727	8033
Down	1.44	46.9	2.64	0.707	6354

Rather surprisingly sex seems not to affect the decision (usually women are more risk-averse), though age does (the older choosing the safer option). Income seems to have some effect, but these numbers should be treated with caution.

We now come to the key part. Of the 622 subjects who chose Up at the first node, 403 chose Up at the second while 219 chose Down. Recall that the theory says that, of those who chose Up at the first choice node, all who plan should choose Up at the second. In this experiment, 219 out of the 622 did not and were therefore inconsistent in their behaviour with the hypothesis that people have a plan and implement it. This is 35% - which is hardly an insignificant proportion. Of the 407 subjects who chose Down at the first node, 255 chose Down at the second while 152 chose Up. Recall that the theory says that, of those who chose Down at the first node, all who plan should choose Down at the second. In the experiment, 152 out of the 407 did not and were therefore inconsistent in their behaviour with the hypothesis that people have a plan and implement it. This is 37% - again a hardly insignificant proportion. Overall, 371 subjects out of 1029 – 36% – had behaviour inconsistent with the hypothesis that people have a plan and implement it. Of the remaining 64% it can be concluded that their behaviour was not inconsistent with the hypothesis that people have a plan and implement it. So in this experiment we can conclude that less than 64% of subjects seem to have a plan and implement it[19].

[19] There is an alternative interpretation. This is one pointed out by my discussant Marc Willinger – and I thank him for it. It could be argued, for example, that those subjects who played *D* at the first node and then *U* at the second if Nature plays *U* and *D* at the second if Nature plays *D* are those subjects who actually prefer the strategy *[D; UD]* to the strategy *[U; UU]* even though they prefer *A* to *B*. Why might this be so? If they have preferences for which *A* is preferred to *B* yet $[A^-,B^+]$ is preferred to $[A^+,A]$. Such preferences are ruled out by Assumptions 1 and 2. But these Assumptions are by no means vacuous. For a non-Expected Utility maximiser to prefer *[900,50]* to *400* for sure and yet prefer the four-ways-equally-likely prospect *[850, 0, 450, 450]* to the four-ways-equally-likely prospect *[950, 100, 900, 50]* is possible – though unlikely.

I must admit that I was surprised by this result. To me the experiment seems excessively simple and the 'correct' procedure so obvious that I had expected that virtually all the subjects would have behaviour consistent with the hypothesis. This expectation had been sharpened by a pilot study that I had done on a sample of subjects from the Bari Summer School in 1999 – in which all 19 subjects had behaviour consistent with the hypothesis. But perhaps that was a bad sample – particularly as they had been lectured to on the subject of consistent dynamic behaviour!

Given this result I had then hoped to be able to 'explain' it by some of the demographic variables. I carried out a number of probit analyses to see if I could explain the consistent/inconsistent decisions. I found nothing. Then I tried something simpler – I constructed the following table showing the average value of certain relevant variables for the two groups. Variables were chosen according to whether they were of potential interest or whether they appeared to have some significance. Variables not included here do not appear to be significant.

Consistent?	Payoff	Sex	Age	Education	Number of children	Net subject income
Yes	494	1.44	44.9	2.74	0.751	7506
No	400	1.48	44.6	2.67	0.623	7134

The column headed 'Payoff' is not an explanatory variable – it is the average payoff of the subjects – but it is interesting to note that consistent subjects make more money than inconsistent ones. I do not think that this is an inevitable implication, but it is interesting nonetheless. The other variables are potential explanatory variables – but they do not seem to explain very much.

A more detailed analysis is provided in the next table, which breaks down the consistent/inconsistent subjects into those who chose Up and those who chose Down at the first choice node. One might think, for example that those initially more risk loving might be more prone to change their minds. It does not seem that this is the case. One thing that does seem to emerge from this table is the feeling that the payoff is higher for the more risk-loving choices; which seems a reasonable result. (I should once again caution against reading too much into the income figures.)

Consistent?	**Payoff**	**Sex**	**Age**	**Education**	**Number of children**	**Net subject income**
Yes (Up at first)	*538*	1.45	43.6	2.75	0.809	7856
No (Up at first)	*373*	1.49	42.9	2.78	0.575	8631

Yes (Down at first)	*425*	1.43	46.9	2.72	0.659	6944
No (Down at first)	*439*	1.47	47.0	2.50	0.691	5372

5. Conclusion

Some 36% of the 1029 subjects in this experiment had behaviour inconsistent with the hypothesis that people have a plan and implement it[20]. This leaves some 64% of subjects whose behaviour was not inconsistent with this hypothesis; but it has to be admitted that some of these subjects too might not have been following a plan. There is of course the point that we should acknowledge from all the experimental work on static decision making under risk – that some of the 36% whose behaviour was inconsistent with the hypothesis may simply have made a mistake. However 36% seems much higher than is usually the case – figures of around 10% to 25% seem more reasonable – though we might expect a figure somewhat higher than in static experiments, given that the nature of the task is more complicated. However, we should, of course, also apply the error story to the 64% of subjects whose behaviour was not inconsistent with the theory – they might have done the 'right thing' by mistake. So the bottom line seems to be that a significant number of subjects in this experiment had behaviour inconsistent with the hypothesis that they had a plan and implemented it.

This conclusion seems to be supported by other experimental evidence. An experiment which tried to discover what people were actually doing in dynamic decision problems, reported in Carbone and Hey (forthcoming), suggests that subjects typically do explore the future possibilities when taking their earlier decisions, but they do so in such a way that ignores what decisions they will be taking in the future. Subjects seem unable to predict their own future behaviour. The experiment reported in this paper seems to confirm this interesting finding.

[20] Under, of course, Assumptions 1 and 2. The conclusions that follow should be qualified by the remarks made in footnote 19 above.

References

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Appendix

Sketch of proof of dynamic consistency requirement.

I consider only the case when the subject prefers *A* to *B*. A similar argument applies in the contrary case. I maintain throughout Assumptions 1 and 2.

I do the proof two ways. I start with backward induction.

In the decision tree there are 6 final gambles and the optimal strategy is determined by the ordering of these 6 gambles. The assumptions I have made above are not sufficient to determine the ordering completely and there are in fact 5 cases that we should consider.

CASE 1 If preference ordering is A+ B+ A A- B B-

If U is played at first node then best at second are UU; if D is played at first node then best at second are UD; this implies a choice between [A+,A] (if U played at first node) and [A-,B+] (if D played at first node). Hence U is best at first and UU at second.

CASE 2 If preference ordering is A+ B+ A B A- B-

If U is played at first node then best at second are UU; if D is played at first node then best at second are DD; this implies a choice between [A+,A] (if U played at first node) and [B,B+] (if D played at first node). Hence U is best at first and UU at second.

CASE 3 If preference ordering is A+ A B+ A- B B-

If U is played at first node then best at second are UU; if D is played at first node then best at second are UU; this implies a choice between [A+,A] (if U played at first node) and [A-,A] (if D played at first node). Hence U is best at first and UU at second.

CASE 4 If preference ordering is A+ A B+ B A- B-

If U is played at first node then best at second are UU; if D is played at first node then best at second are DU; this implies a choice between [A+,A] (if U played at first node) and [B,A] (if D played at first node). Hence U is best at first and UU at second.

CASE 5 If preference ordering is A+ A A- B+ B B-

If U is played at first node then best at second are UU; if D is played at first node then best at second are UU; this implies a choice between [A+,A] (if U played at first node) and [A-,A] (if D played at first node). Hence U is best at first and UU at second.

I now do the proof using strategies:

There are eight possible strategies with each of which are associated two equally likely final prospects. These are as follows:

(U; UU) *[A^+, A]*

(U; UD) *[A^+, B^-]*

(U; DU) *[B, A]*

(U; DD) *[B, B^-]*

(D; UU) *[A^-, A]*

(D; UD) *[A^-, B^+]*

(D; DU) *[B, A]*

(D; DD) *[B, B^+]*

It is clear that if *A* is preferred to *B* and if my assumption holds then U; UU is the best strategy:

[A^+, A] is preferred to *[A^+, B^-]* through Assumptions 1 and 2

[A^+, A] is preferred to *[B, A]* through Assumptions 1 and 2

[A^+, A] is preferred to *[B, B^-]* through Assumptions 1and 2

[A^+, A] dominates *[A^-, A]*

[A^+, A] is preferred to *[A^-, B^+]* through Assumptions 1 and 2

[A^+, A] is preferred to *[B, A]* through Assumptions 1 and 2

[A^+, A] is preferred to *[B, B^+]* through Assumptions 1 and 2