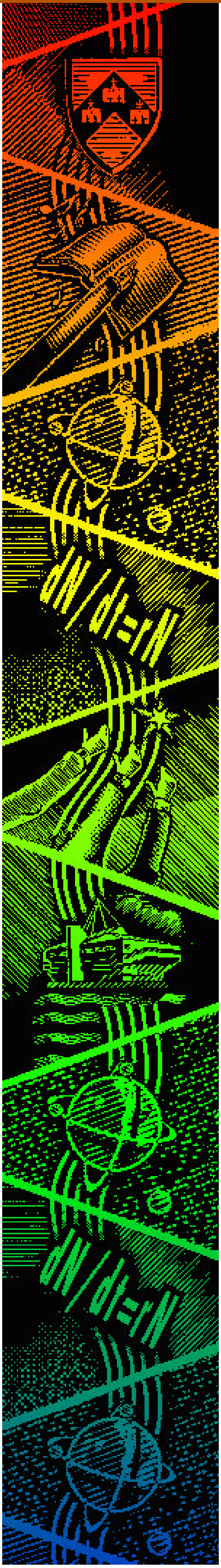

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Dynamic Choice and Timing-Independence: An Experimental Investigation

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Dynamic Choice and Timing-Independence: an experimental investigation.

by

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Abstract: Timing-independence implies that individuals are indifferent between a sequential choice problem and a planned choice problem which are strategically equivalent except for the timing of resolution of the uncertainty. This paper reports an experiment in which we investigate whether the timing of resolution of the uncertainty affects individual preferences. We elicit individual preferences for three strategically equivalent decisions problems. The experimental results suggest that timing-independence is an inappropriate assumption of individual preferences. The paper discusses possible implications of such findings.

JEL classifications: D81, C91, D90

Keywords: Dynamic decision making, Experiments, Timing-independence, Strategic equivalence.

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Introduction

The interpretation of a sequential (that is, dynamic) choice problem as a planned choice problem is widely supported by economists and decision theorists. The sequential choice problem is reduced to a non-sequential choice problem by the adoption of a plan (that is, of a decision strategy) as a tool to manage time in dynamic decision making. This reduction requires the decision-maker to be indifferent between choice problems that are strategically equivalent, except for the timing of resolution of the uncertainty. This means that the decision-maker is required to be indifferent between early or later resolution of the uncertainty, on the assumption that individual preferences are timing-independent or timing-invariant.

Recent works (see McClennen,1990; Cubitt, 1996; Cubitt *et al.*, 1998) have suggested that the independence axiom of expected utility theory can be interpreted as a combination of principles of rational dynamic choice. The assumption of timing-independence is explicitly expressed as one of these principles; and it is endorsed by the theories of dynamic choice[1]. However, whether timing-independence is endorsed by common people is a different matter. Indeed an important question about this principle is whether individuals in practice are indifferent between strategically equivalent sequential and planned choice problems. In other words, the question is whether individual preferences are affected by the timing of the resolution of the uncertainty. The research reported here concentrates on this particular issue. We present an experiment in which we elicited subjects' preferences for three strategically equivalent choice problems, namely a sequential choice problem, a planned choice problem and a non-sequential choice problem. This experiment allowed us to investigate whether timing-independence is an appropriate assumption of individual preferences in practice.

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[1] See, Kahneman and Tversky (1979), Machina (1989), Segal (1989, 1990), Karni and Schmeidler (1991). An important interpretation of dynamic choice behaviour is given by Strotz (1956), McClennen (1990), Karni and Safra (1989, 1990). They interpret the dynamic choice problem as an intrapersonal choice problem, between the present self and the future self of the same agent. Before the resolution of any uncertainty, the present self (pre)commits to a course of action to which the future self has to conform in order to avoid dynamically inconsistent choice behaviour. In this case, the (pre)commitment of the present self enforces timing-independence, which otherwise would be violated by the future self.

The paper is organized as follows. Section I sets up the theoretical background to the experiment. The design is contained in Section II. Section III reports the experimental results and Section IV concludes.

I. Theoretical background

In normative decision theory a sequential decision problem is usually reduced to a problem of planning, that is to a sequence of choices consistent with those specified in the plan adopted at the initial stage of the decision problem. Hammond (1988a, 1988b) showed that consequentialism is the axiom, automatically satisfied by expected utility theory, which justifies the reduction of a sequential choice problem to a planned choice problem.

Given the consequentialist axiom that choice behaviour is explicable by its consequences, a plan should specify a consistent choice behaviour for every choice node in any pair of strategically equivalent decision trees representing the decision problem[2]. By "strategically equivalent" we mean that the decision trees imply the same opportunity set of probability distributions of (final) consequences or, simply, the same set of risky consequences; where each risky consequence generates from a single plan[3]. In other words, the plan should prescribe equivalent choice behaviour in any pair of equivalent decision trees regardless of their timing of resolution of uncertainty. This means that agents facing a sequential decision problem are required to adopt a plan prescribing a sequence of choices corresponding to a feasible set of risky consequences in the equivalent non-sequential form of the decision problem.

As an illustration consider the decision tree T_1. Following the usual convention, squares denote decision nodes and circles denote chance nodes (Raiffa, 1968). The decision problem represented in T_1 is a *sequential choice problem*. Indeed, the chance node is followed by a choice node; and the

[2] This is the definition of plan given in Hammond (1988a, 1998b). McClennen (1990) and Cubitt (1996) adopt a different definition of plan, which specifies choices to be made at each choice point that can be reached by implementation of earlier stages of the adopted plan. As McClennen (1990, p. 282) points out, this definition enforces dynamic consistency to be an objective rather than an implication of rational behaviour.
[3] The plan should reveal a unique choice function. See Hammond (1988a, 1988b) and Cubitt (1996).

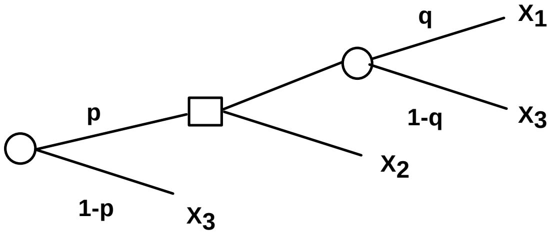
choice problem involves choices taken after the resolution of some of the uncertainty. The elements of the opportunity set are probability distributions over the consequences (x_1, x_2, x_3). The opportunity set of risky consequences implied by T_1, and the plans which produce each of them are listed below:

P_1: $(x_3, 1-p; x_2, p)$

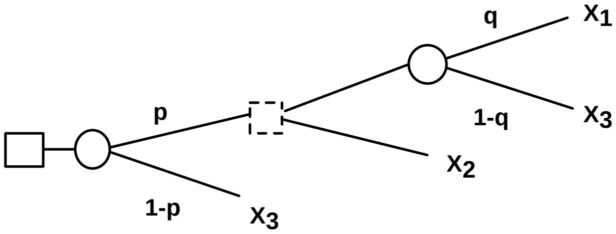
P_2: $(x_3, 1-p; x_1, pq; x_3, p-pq)$

P_1 specifies the choice of the lower branch, and P_2 the choice of the upper branch. Here, choosing P_1 gives a (1-*p*) chance of receiving x_3, and a *p* chance of receiving x_2; while choosing P_2 gives a (1-*p*) chance of receiving x_3, a *pq* chance of receiving x_1, and a (*p*-*pq*) chance of receiving x_3. In a consequentialist setting, the agent facing the sequential choice problem is required to choose a single plan at the root of the decision tree. This situation, represented in T_2, depicts a *planned choice problem*. The decision tree T_2 is strategically equivalent to T_1, but at the *first* choice node the agent is required to adopt either P_1 or P_2. This implies that the choice to be made at the second broken choice node is anticipated before the resolution of the uncertainty. The adoption of a plan changes the timing of the choice, reducing the sequential decision problem to a single choice at the first choice node.

T_1:

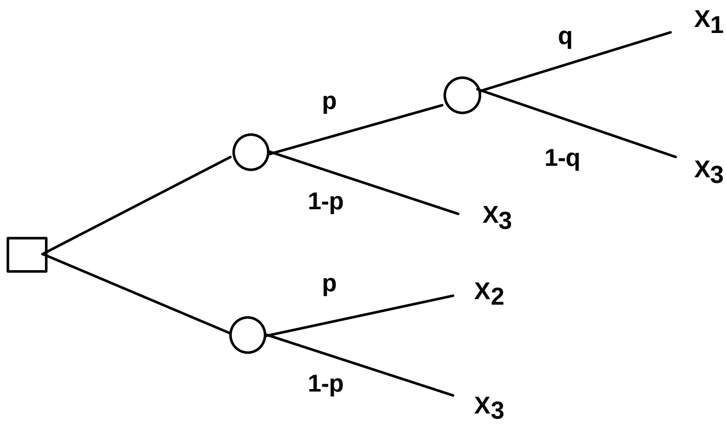


T_2:



Hence the situation represented in T_1 can be alternatively represented as in T_3.

T_3:



The decision problem represented in T_3 is a *non-sequential choice problem.* It is strategically equivalent to T_1 and T_2, but it abstracts away from the sequential features of T_1. In fact, it is the standard (that is, static) formulation of the sequential choice problem represented in T_1.

The next section presents an experiment in which we elicited subjects' preferences for three strategically equivalent decision problems, as represented in T_1, T_2 and T_3, by finding out what they were willing to pay for playing out each of them.

II. The experimental design

The experiment was conducted at **EXEC** (the Centre for Experimental Economics at the University of York). A total of 40 students, both graduate and undergraduate, took part in this computer-based experiment. Subjects were presented with three triples of decision problems. Each triple consisted of three strategically equivalent decision problems, namely a sequential choice problem (T_1), a planned choice problem (T_2), and a non-sequential choice problem (T_3). The plans available in each triple of decision problems are listed in Table 1. The subjects were asked to state their maximum willingness to pay (WTP) for playing out each decision problem presented in each triple

- nine decision problems in total. To elicit subject's preferences we adopted an English Clock Auction, which is an incentive compatible variant of the classical second-price auction[4].

[Insert table 1 about here]

Each subject sat in front a computer terminal. After the instructions (see Appendix A) were read out, each subject was given three sheets of paper. On each sheet there was the full description of each triple of decision problems (see Appendix B). Subjects were given 15 minutes to read carefully the description of all the decision problems presented. Before starting the experiment proper, subjects were given a practice triple of decision problems in order to acquire experience with the incentive compatible nature of the second price auction mechanism, and with the decision problems. The practice triple presented probability distributions over the monetary outcomes different from the proper triples. When the auction started, the experimenter announced the first decision problem (T_1) of Triple 1. The problem was shown on the computer screen. After two minutes the auction started: at the bottom of the screen was a counter in pounds and pence which was steadily increasing, starting from a price of zero. Subjects entered their bids by pressing any key when the counter reached the highest amount they were willing to pay for playing out the decision problem. The same procedure was followed for all decision problems, which were auctioned sequentially. No information about the winner of the auction nor the individual bids were given to the participants at the end of any auction. After all nine decision problems were auctioned, one problem was selected at random. For that choice problem, the first and second highest bids were announced. The subject who had made the highest bid was required to pay the second highest bid, before playing out for real the decision problem selected. The decision problem selected was played out following the procedure described in the problem. At the end he or she was given a

[4] For this type of clock auction, see Harstad (1990). An application is in Di Mauro and Maffioletti (1996).

participation fee of £5 (English pounds) plus the amount of money eventually gained playing out the decision problem. All the other participants were given the participation fee of £5.

III. Results

The results of the experiment are summarized in Table 2. The tests involved cross comparisons of mean WTP values elicited for each decision problem, namely WTP_{T_1}, WTP_{T_2} and WTP_{T_3}.

[Insert table 2 about here]

In order to investigate whether the timing of the resolution of the uncertainty is irrelevant for individual preferences, we tested the hypothesis that subjects are indifferent between T_1, T_2 and T_3. This implies that $WTP_{T_1} = WTP_{T_2} = WTP_{T_3}$. The hypothesis of equality of means in each triple was tested through the analysis of variance (ANOVA). We carried out also a non-parametric test, that is a Kruskal-Wallis test. The results of the ANOVA and Kruskal-Wallis tests are shown in Table 3.

[Insert table 3 about here]

ANOVA results from triple 1, triple 2 and triple 3 suggest the rejection of the null hypothesis of equality of means (with a p value less than 0.001). The non-parametric Kruskal-Wallis test leads to the same conclusion. These results suggest that subjects do not consider as equivalent decision problems which are strategically equivalent. Then we carried out both t-tests and Mann-Whitney tests to pinpoint which WTP means are different from each other in each triple of decision problems. The results are shown in table 4.

[Insert table 4 about here]

The results of these tests suggest the rejection of the null hypothesis that $WTP_{T_1} = WTP_{T_2}$ and $WTP_{T_2} = WTP_{T_3}$ in all triples; while they do not suggest the rejection of the null hypothesis that $WTP_{T_1} = WTP_{T_3}$ in all triples. This means that subjects do not consider the planned choice problem as equivalent to both sequential and non-sequential choice problems; while they do consider as substantially equivalent the sequential choice problem and the non-sequential choice problem. Evidently, the anticipation of resolution of the uncertainty implied by the planned choice problem appears to affect subjects' preferences.

IV. Concluding Remarks

An important principle of rational dynamic choice assumes that individual preferences are timing-independent. Timing-independence implies that individuals are indifferent between a sequential choice problem and a planned choice problem, which are strategically equivalent except for the timing of resolution of the uncertainty. We have designed and carried out a simple experiment to investigate whether the timing of resolution of the uncertainty affects individual preferences. We have elicited subject's preferences for three stategically equivalent choice problems by finding out what they were willing to pay for playing out each of them. This allowed us to investigate how subjects respond to early or later resolution of uncertainty.

Our experimental results suggest that timing-independence is an inappropriate assumption of individual preferences. This result is of particular interest when taken in conjunction with the experimental results of Cubitt *et al*. (1998), which reject the hypothesis that subjects' choices satisfy the principle of timing-independence[5]. In particular, our findings suggest that subjects are not

[5] The analogy between our findings and those of Cubitt *et al*. (1998) emerges from two crucially different investigations of timing-independence. In our experiment we test subjects' preferences for different presentations of the decision problem; while Cubitt *et al.* test whether subjects' choice behaviour differs depending on the presentation of the decision problem. It could of course be the case that subjects prefer particular presentations while behaving the same in all presentations, or that subjects are indifferent between different presentations whilst behaving differently. The two issues are conceptually quite different.

indifferent between strategically equivalent choice problems. Indeed, subjects do not consider the planned choice problem as equivalent to sequential and non-sequential choice problems. This result is important, for it suggests that the anticipation of resolution of future uncertainty, imposed by planned decision, may be the reason why decision-makers do not endorse planning as a strategy to solve sequential choice problems. In this case, the possible explanations may be: that subjects are not willing to anticipate the future uncertainty for they do not know what their future preferences will be (see Loewenstein and Adler (1995), Loewenstein (1996)); or that subjects are not willing to anticipate the future uncertainty for they have a preference for procrastination rather than anticipation of decisions (e.g. Thaler and Shefrin (1981); Akerlof (1991)). Thus, an implication of our experimental results points to the opportunity of further investigation of subjects' preferences for early or later resolution of the uncertainty, which may be important to explain intertemporal decisions such as consumption and savings decisions (e.g. Kreps and Porteus (1978, 1979), Epstein (1980), Machina (1984), Chew and Epstein (1989)). Finally, our findings raise the question of whether timing-independence may be retained as a normative principle if the timing of resolution of uncertainty does affect individual preferences.

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TABLES

Table 1. Plans available in each triple of choice problems

	Probability Distribution
Triple 1	(0,.70; 4,.30); (0,.70; 0,.06; 12,.24)
Triple 2	(0,.40; 4,.60); (0,.40; 0,.12; 7,.48)
Triple 3	(0,.70; 4,.30); (0,.70; 0,.24; 40,.06)

Table 2. Summary of Results (all amounts in pounds sterling)

	choice problem	mean WTP	median WTP	standard deviation
	T_1	4,51	4,55	1,942
Triple 1	T_2	2,42	2,40	1,264
	T_3	3,92	3,90	1,823
	T_1	3,30	3,245	1,152
Triple 2	T_2	1,93	1,99	7,820
	T_3	3,24	3,32	8,232
	T_1	7,77	7,89	2,596
Triple 3	T_2	4,06	3,95	1,791
	T_3	6,99	7,10	3,058

Table 3. ANOVA and Kruskal-Wallis Tests

	Hypothesis	ANOVA $F_{(2,57)}$	P-value	Kruskal-Wallis test $\chi^2_{(2)}$	P-value
Triple 1	$WTP_{T_1} = WTP_{T_2} = WTP_{T_3}$	8.027	.001	13.213	.001
Triple 2	$WTP_{T_1} = WTP_{T_2} = WTP_{T_3}$	13.693	.000	22.091	.000
Triple 3	$WTP_{T_1} = WTP_{T_2} = WTP_{T_3}$	11.849	.000	17.640	.000

Table 4. The results of t-test and Mann-Whitney test

	Hypothesis	T-statistic	P-value	U-statistic	P-value
Triple 1	$WTP_{T_1} = WTP_{T_2}$	-4.039	.000	75	.001
	$WTP_{T_1} = WTP_{T_3}$	.997	.325	161.5	.298
	$WTP_{T_2} = WTP_{T_3}$	-3.021	.005	101	.007
Triple 2	$WTP_{T_1} = WTP_{T_2}$	4.387	.000	52.5	.000
	$WTP_{T_1} = WTP_{T_3}$	.178	.859	190	.786
	$WTP_{T_2} = WTP_{T_3}$	-5.156	.000	48.5	.000
Triple 3	$WTP_{T_1} = WTP_{T_2}$	-5.251	.000	50.5	.000
	$WTP_{T_1} = WTP_{T_3}$	.871	.390	172	.457
	$WTP_{T_2} = WTP_{T_3}$	-3.688	.001	87	.002

Appendix A

Thank you for taking part in this experiment. Please follow these instructions carefully and remember that during the experiment you are not allowed to talk with anyone nor to look at what anyone else is doing in the experiment.

You will be presented with three triples of decision problems. Each triple gives three different presentations of a decision problem.

At the beginning of the experiment the experimenter will distribute three sheets of paper. On each sheet you will find the full description of each triple of decision problems. You will be given 15 minutes to read carefully the description of all the decision problems presented. Then, you will be asked to state the maximum amount you are willing to pay for playing out each decision problem of the triple. You will indicate your willingness to pay through the following auction mechanism.

On the screen you will see a description of the decision problem. Below the description, at the bottom of the screen, will be shown a counter in pounds and pence which will steadily increase. You will indicate your willingness to pay by pressing any key when the counter reaches the highest amount that you are willing to pay. After you have revealed your willingness to pay for all the decision problems (nine decision problems in total), one of the problem will be selected with a random device and that problem will be played out for real. The player who states the highest willingness to pay for that problem will be required to pay the second highest bid, before playing out the problem selected. She or he will receive a participation fee of £5 (English pounds) plus the amount of money eventually gained playing out the decision problem. All the other participants will receive the participation fee.

The experiment is organised as follows:

Step1. You will be given a practice triple of decision problems in order to help you to become familiar with the auction procedure and with the decision problems. The highest bidder will play out the decision problem and the payment procedure will be showed.

Step 2. The experimenter will announce the first choice problem of the first triple. You will be allowed two minutes to think about it.

Step 3. The auction will take place. You will be asked to press a key when the counter reaches the highest amount that you are willing to pay.

Step 4. After all decision problems have been auctioned, one problem will be selected at random and played out for real. One of the participants will be asked to pick a number from a bag containing 9 chips numbered from 1 to 9. Each number corresponds to one of the decision problems. If, say, number 5 is picked, then the experimenter will enter that number into the the control computer (please, notice that at the end of the experiment you can check the number of the chips in the bag). At this point, the screen will show all the prices at which each subject dropped out from the auction. If you are the highest bidder you will play out the decision problem for real. The decision problem selected will be played out following the procedure described in the problem. You will receive the participation fee plus the amount of money eventually gained playing out the decision problem. All the other participants will receive the participation fee.

Appendix B

TRIPLE 1

Problem 1

You have a decision problem.

In stage 1 the experimenter will draw a chip from the bag:

if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.
If you reach stage 2 you have a choice between:
(a) receiving £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £12; if the chip is numbered 9-10 you will receive nothing.

Problem 2
You have a decision problem.
In stage 1 you have to committ to either (a) or (b), which you will get in the event of reaching stage 2: (a) you will receive £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £12; if the chip is numbered 9-10 you will receive nothing.
After you declare your commitment, the experimenter will draw a chip from the bag:
if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.
Depending on what you have committed to choose, you will get (a) or (b).

Problem 3
You have a decision problem.
In stage 1 you have to choose either (a) or (b):
(a) the experimenter will draw a chip from the bag: if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will receive £4.
(b) the controller will draw a chip from the bag:
if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.
If you reach stage 2, the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £12; if the chip is numbered 9-10 you will receive nothing.

TRIPLE 2
Problem 1
You have a decision problem.
In stage 1 the experimenter will draw a chip from the bag:
if the chip is numbered 1-4 you will receive nothing; if the chip is numbered 5-10 you will reach stage 2.
If you reach stage 2 you have a choice between:
(a) receiving £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £7; if the chip is numbered 9-10 you will receive nothing.

Problem 2
You have a decision problem.
In stage 1 you have to committ to either (a) or (b), which you will get in the event of reaching stage 2: (a) you will receive £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £7; if the chip is numbered 9-10 you will receive nothing.

After you declare your commitment, the experimenter will draw a chip from the bag:
if the chip is numbered 1-4 you will receive nothing; if the chip is numbered 5-10 you will reach stage 2.
Depending on what you have committed to choose, you will get (a) or (b).

Problem 3
You have a decision problem.
In stage 1 you have to choose either (a) or (b):
(a) the experimenter will draw a chip from the bag: if the chip is numbered 1-4 you will receive nothing; if the chip is numbered 5-10 you will receive £4.
(b) the controller will draw a chip from the bag:
if the chip is numbered 1-4 you will receive nothing; if the chip is numbered 5-10 you will reach stage 2.
If you reach stage 2, the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive £7; if the chip is numbered 9-10 you will receive nothing.

TRIPLE 3
Problem 1
You have a decision problem.
In stage 1 the experimenter will draw a chip from the bag:
if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.
If you reach stage 2 you have a choice between:
(a) receiving £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive nothing; if the chip is numbered 9-10 you will receive £45.

Problem 2
You have a decision problem.
In stage 1 you have to committ to either (a) or (b), which you will get in the event of reaching stage 2: (a) you will receive £4, or (b) the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive nothing; if the chip is numbered 9-10 you will receive £45.
After you declare your commitment, the experimenter will draw a chip from the bag:
if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.
Depending on what you have committed to choose, you will get (a) or (b).

Problem 3
You have a decision problem.
In stage 1 you have to choose either (a) or (b):
(a) the experimenter will draw a chip from the bag: if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will receive £4.
(b) the controller will draw a chip from the bag:
if the chip is numbered 1-7 you will receive nothing; if the chip is numbered 8-10 you will reach stage 2.

If you reach stage 2 the experimenter will draw a chip from the bag:
if the chip is numbered 1-8 you will receive nothing; if the chip is numbered 9-10 you will receive £45.

(Please, notice that the bag contains 10 chips, and that every time a chip is drawn it will be replaced in the same bag. At the end of the experiment you can check the number of the chips in the bag)