A quantitative and qualitative test of the Allais paradox using health outcomes

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Abstract

There have been many tests of the descriptive validity of the axioms of expected utility theory (EU) using money outcomes. Such tests are relatively uncommon with respect to health outcomes. This is unfortunate, because the standard gamble - considered by many health economists to be the gold standard for cardinal health state value assessment - is implied from the axioms of EU. In this paper, the classic Allais paradox, which predicts a systematic violation of the independence axiom, is tested in the context of health outcomes. Seventeen of 38 participants demonstrated strict violations of independence, with 14 of these violating in the direction predicted by Allais. The violations were thus significant and systematic. Moreover, the participants' qualitative explanations for their behaviour show seemingly rational and not inconsistent reasoning for the violations. This evidence offers a further challenge to the descriptive validity of EU, and underlines the need to test alternative theories of risk and uncertainty in the context of health outcomes.

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1. Introduction

Cardinal health state value assessment is undertaken with a variety of techniques. The most common instruments are the standard gamble, the time trade-off and the visual analogue scale. Health care decisions invariably involve risk. The time trade-off and the visual analogue scale do not internalise attitudes toward risk. If we assume that risk attitude is a relevant component of the individual's utility function, these instruments therefore lack validity in eliciting health state values in contexts where outcomes are uncertain. The standard gamble, however, is implied from the axioms of expected utility theory (EU), and thus has a firm basis in the theory of risk and uncertainty. It is for this reason that the standard gamble has been reported to be the gold standard in the measurement of cardinal health state values (Torrance, 1986), though, admittedly, some challenge this view (Wakker & Stiggelbout, 1995).

The foundations of EU were laid in the 1940s (von Neumann & Morgenstern, 1944). However, since the 1950s, the descriptive validity of EU has been increasingly discredited through the empirical testing of its axioms (for a review, see Camerer, 1995). Most of this empirical testing has been undertaken in the context of money outcomes. There have been few direct attempts at testing the descriptive validity of EU in the context of health care (Wakker & Stiggelbout, 1995), though there is some evidence to suggest that the independence axiom is compromised in risky health-related scenarios (e.g., Bleichrodt & Johannesson, 1996; Llewellyn-Thomas, Sutherland, Tibshirani, Ciampi, Till & Boyd, 1982; Rutten-van Molken, Bakker, van Doorslaer & van der Linden, 1995; Spencer, 1998). Indeed, it is the independence axiom that has generally been subject to most of the criticism of EU.

Independence implies that the intrinsic value that an individual places on any particular outcome in a gamble will not be influenced by the other possible outcomes (either within that gamble or within other gambles to which the gamble is being compared), or by the size of the probability of the outcome occurring. The axiom requires that, when comparing gambles, all common outcomes that have the same probability of occurring will be viewed by the individual as irrelevant. This requirement can be demonstrated with the aid of Table 1.

[Insert Table 1]

In Table 1, gambles A, B, A' and B' are presented in a collapsed format. It can be seen from Table 1 that, with a probability 0.89, A and B share a common outcome of $1million and A' and B' share a common outcome of $0. In all other respects A is identical to A' and B is identical to B'. Consider the case where an individual is asked to choose between both A and B, and A' and B'. Assuming independence, the individual's preferences should be unaffected by changes in the common outcome between choice contexts. Therefore an individual who prefers A (B) in the choice between A and B should prefer A' (B') in the choice between A' and B'.

In a famous criticism of EU, Maurice Allais argued that under certain conditions individuals will systematically violate independence (Allais, 1953). In a non-collapsed format, A, B, A' and B' in Table 1 can be presented as:

A: 10% chance of $5m, 89% chance of $1m, and 1% chance of nothing

B: $1m for certain
A': 10% chance of $5m and 90% chance of nothing
B': 11% chance of $1m and 89% chance of nothing

Allais argued that when individuals are faced with choices between A & B and A' & B' in the non-collapsed format, many individuals will display a preference for B and A', which violates the independence axiom. Allais' proposition is known as the Allais paradox (or the common consequence effect), and has been empirically supported in subsequent analyses (Camerer, 1989; Conlisk, 1989; Kahneman & Tversky, 1979; MacCrimmon & Larsson, 1979; Morrison, 1967; Moskowitz, 1974; Slovic & Tversky, 1974).

An explanation for the Allais paradox is the certainty effect, where it is suggested that some people will overweight outcomes that are considered certain relative to those that are merely probable (Kahneman & Tversky, 1979). There are several, possibly interdependent, explanations for the certainty effect. For example, the effect may be associated with the commonly observed propensity for people to demonstrate loss aversion (e.g., Tversky and Kahneman, 1991). Loss aversion is the psychological process that induces people to perceive losses to loom larger than gains. That is, the disutility that individuals seemingly suffer from losses is of significantly greater magnitude than the utility they enjoy from gains of the same absolute size (e.g. the disutility of losing $50 is of significantly greater magnitude than the utility of winning $50).

In terms of the Allais-type introduced by Allais, loss aversion may be particularly strong in the choice between A and B. This is because individuals have the opportunity to avoid completely the possibility of winning nothing in this choice. Since B offers $1m for certain, the $1m may serve as a 'reference point', and thus winning nothing may be perceived as a loss that people will be particularly keen to avoid. However, in the choice between A' and B', both gambles offer a high probability of winning nothing. The individual's reference point may have therefore fallen, perhaps almost as low as $0, and thus the extent to which winning nothing is perceived as a loss may have significantly diminished. Compared to the choice between A and B, this cognitive process would weaken the influence of loss aversion on decision making behaviour and prompt many individuals to base their decision on the size of the best possible outcome rather than the avoidance of the worst possible outcome. Hence, the commonly observed preferences for B and A'.

A second possible psychological process that may underlie the certainty effect is anticipated regret (Bell, 1982; Loomes & Sugden, 1982; 1987a; b). For example, people may expect their regret to be greater should they realise a poor outcome in a choice context where the poor outcome could have been entirely avoided than in a choice context where there is always some chance that the poor outcome will occur. A complementary theory of disappointment has also been formulated (Loomes & Sugden, 1986). Whereas anticipated regret modifies the values that people place on outcomes in accordance with the likely corresponding outcomes *across different gambles*, anticipated disappointment modifies the value that people place on the gamble in relation to the potential outcomes contained *within that same gamble*. For example, people know they will be successful if they choose B; their expected utility of B will be the utility they derive from $1m. In A their chances are also excellent;

should they choose this gamble and win nothing they anticipate their disappointment to be severe. This anticipated disappointment may therefore significantly decrease their expected utility of A. However, in the choice between A' and B', they may expect to win nothing whatever they choose, and will therefore feel relatively little disappointment if they should win nothing. Since the chances of winning in A' and B' are similar, they may simply opt for the option with the highest potential outcome.

A cognitive process that applies to the probabilities rather than the outcomes has also been put forward as an explanation of the common consequence effect, and relates to evidence that individuals tend to transform probabilities so as to overweight small probabilities and underweight large probabilities (e.g., Bleichrodt & Pinto, 2000; Bleichrodt, van Rijn & Johannesson, 1999; Gonzalez & Wu, 1999; Lattimore, Baker & Witte, 1992; Tversky & Fox, 1995; Tversky & Kahneman, 1992; Wu & Gonzalez, 1996; 1999). The significance of probability transformation as a possible explanation for the Allais paradox is that people may perceive the difference between the 0% and 1% chance of winning nothing in B compared to A as greater than that between the 89% and 90% chance of winning nothing in B' and A'. Thus, we have a further possible psychological reason for why people may systematically prefer B and A'.

The objective of this paper is to quantitatively and qualitatively assess compliance with the independence axiom in Allais-type health contexts. Qualitative evidence is gathered in an attempt to better understand the reasoning behind people's preference patterns, and, if violations of independence occur, whether their reasoning conforms with the main hypotheses that have been put forward to explain the Allais paradox. Other important features of the analysis are that it represents a rare attempt at directly testing the descriptive performance of EU in the context of health outcomes, and that the common outcomes in the Allais contexts are presented to the participants in an explicit, collapsed format. This gives added weight to the claim that any evidence of the Allais paradox is accounted for by a deliberate failure of independence rather than by the participants having insufficient time or ability to unpack the alternatives on offer.

2. Methods

2.1. Participants

The participants were recruited in June 1999 from the staff of a large health care-related organisation situated in London. No payment was offered to the participants in this study.

Thirty-eight people agreed to participate. To obtain agreement to undertake the study, the author had to guarantee that the participants would remain strictly anonymous. Therefore, very little information on the construct of the participant population can be given. It can be stated that participants were recruited from all grades within the organisation - i.e. from the general office staff to the directors - and that 55% (21/38) were women. The participants partook in the study in nine groups of between two and six people during July and August 1999.

2.2. Design

The results reported in this paper area nested part of a larger study in which each participant was presented with 20 health care contexts. In order to gain and maintain the full understanding and interest of the participants, the study was designed with the aim of presenting the contexts with as much clarity as possible. With this in mind, the options in each context were presented in pie chart format where the outcomes and associated percentage chances of occurring were explicitly stated. The two Allais-type contexts used in this study are presented in Figures 1 and 2.

[Insert Figures 1 and 2]

As detailed in Figures 1 and 2, the participants were asked to imagine that they have an illness from which, without treatment, they would die almost immediately, and that their doctor tells them that there are two alternative treatments for their illness. The construction of the two pies in each context illustrates the chances of particular outcomes from the two available treatments. Note that in order to make things as simple as possible for the participants, outcomes are framed in terms of healthy life expectancy rather than more complicated outcome measures, such as multi-dimensional health state descriptions.

Each participant was asked to rate the treatments (a) and (b) on a scale, which had the outcome of an unavailable treatment - 30 years in full health followed by death - at the top of the scale, and the outcome of no treatment - immediate death - at the bottom of the scale. Indifference could be indicated by rating both treatment options at the same point on the scale. It was emphasised that this was an ordinal rating; the participants were informed that the differences between their ratings of treatment options would not be taken as an indication of the strength of their preferences. No effort was made to measure cardinality in this study. The participants were informed that there are no right or wrong answers to any of the contexts, and the order in which the contexts were presented was randomised across participants.

The reason why the participants were asked to rate the alternatives in each context on a scale rather than to directly choose between treatments (a) and (b) was because the larger questionnaire in which the Allais-type contexts were nested contained many contexts in which the two treatment alternatives shared a common outcome. If the participants had been asked to choose directly between treatment options, they may have soon learned that many contexts contain options with a common outcome. This could have led them to search for and cancel any common outcomes before evaluating the available options with the appropriate level of care and consideration. Such an occurrence would represent an immediate focus on a particular outcome and could give rise to a cognitive process that would hardly, if ever, be induced in real world settings. It was thus considered important to reduce the possibility of an unnatural and immediate focus upon any particular outcome. It was thought that by asking the participants to rank each treatment on a scale that was marked with the endpoints of living for 30 years and immediate death (i.e. endpoints that did not share the common outcomes in the treatment options), they would be more likely to consider all outcomes in each treatment option before indicating a preference.

In order to comply with the Allais paradox, treatments (a) and (b) in Figure 1 share the common outcome of an 89% chance of living for 12 years in full health then death, and treatments (a') and (b') in Figure 2 share the common outcome of an 89% chance of immediate death. It is easy to observe that if the respective common outcomes are disregarded, the two contexts are identical. According to the independence axiom, individuals should rate (a') higher than (b') if they rate (a) higher than (b), or (b') higher than (a') if (b) higher than (a) (or they should express indifference in both contexts). Preference patterns (a) then (b') or (b) then (a') represent strict violations of independence. To test whether any observed violations of independence are systematically in the direction of that predicted by Allais - i.e. (b) then (a') - the chi-squared (χ^2) statistic, denoted $\chi^2_n(m)$ where n is the level of significance and m in the number of degrees of freedom, is used.

In order to familiarise the participants with the general format of the contexts, and in anticipation that some participants might find treatment options that include two different percentage chances of the same outcome strange (as in option (b) in Figure 1), all participants were given three practice contexts before they answered the full questionnaire. One of the practice contexts was identical to Figure 2, which also appeared in the full questionnaire. In order to ensure that participants fully understood the contexts placed before them, they were allowed to ask questions during the practice session. All participants were informed that though the presentation of some options may appear strange, they should answer as best they can according to their own individual preferences. All participants stated that they understood and were happy with the presentation of the contexts before they began the full questionnaire, which they were required to answer without conferring and without asking any questions. Whilst answering the full questionnaire, the participants were free to return to previous contexts in order to revise their answers.

After each context, the participants were asked to write down briefly in their own words the reason for their rating of the two treatment options. This was undertaken to attain qualitative evidence concerning the cognitive processes underlying the participants' decisions.

RESULTS

Quantitative results

In presenting the results, it is necessary to refer to contexts 1 and 2 in Figure 1. Table 2 shows the preference patterns observed after participants had rated treatment (a) against (b), and (a') against (b').

[Insert Table 2]

In Table 2, preference pattern (a) (a') refers to a situation where treatment (a) is rated higher than (b) in context 1 of Figure 1, and (a') is rated higher than (b') in context 2. All other preference patterns can be read similarly. The symbol (I) refers to a context

where the participant is indifferent between the two treatment options. Of the observed preference patterns, (a) (a') and (b) (b') are consistent with the independence axiom. Preference patterns (a) (b') and (b) (a') represent strict violations of independence.

Twenty of the 38 participants (52.6%) violated independence. This compares with violation rates of around 30-60% in studies that have incorporated money outcomes. Of the 18 participants whose preferences were consistent with independence, 14 (77.8%) exhibited preference pattern (a) (a').

It has been suggested that violations of independence are the result of errors.[32-34] If so, it is expected that the violations will be roughly equally split in both directions. That is, participants would be expected to exhibit patterns (a) (b') and (b) (a') in roughly equal numbers. In common with much evidence published in terms of money outcomes,[5-8,17-19] the results in Table 2 show that this is not the case. Fourteen of the 17 participants (82.4%) who demonstrated strict violations of independence exhibited preference pattern (b) (a') ($\chi^2 = 7.12 > \chi^2_{.05}(1) = 3.84$), which accords with the Allais hypothesis.

As mentioned earlier, partly as a test of consistency, one of the practice contexts given to the participants before they completed the main questionnaire was identical to context 2 in Figure 1. Twenty-six participants (68.4%) gave consistent answers for these two contexts.

Qualitative results

The qualitative results concerning only the two main preference patterns are noted here, which should be read with reference to Figure 1*.

For participants demonstrating preference pattern (a) (a') (N = 14), there were two main patterns of explanations given for their preferences:

(i) Treatment (a) was preferred over (b) because the risk of the 1% chance of death is worth taking for the 10% chance of living for 18 years in full health, and (a') was preferred over (b') for the same reason (N = 4).

(ii) Treatment (a) was preferred over (b) because the risk of the 1% chance of death is worth taking for the 10% chance of living for 18 years in full health, and (a') was preferred over (b') because the difference between a 10% and an 11% chance of a positive outcome is negligible, so one might as well choose the option that offers a chance of living for 18 years (N = 5).

Both of these sets of explanations resulted in preferences that accord with the independence axiom. Participants who offered the first set of explanations gave identical, and thus perfectly consistent, explanations for preferring (a) and (a').

* The participants who expressed preference patterns (a) (a') or (b) (a') but who are not reported to have followed one of the main patterns of explanations, failed to give a qualitative explanation for at least one of their answers.

Participants who offered the second set of explanations used different thought processes for preferring (a) and (a'), both of which are perfectly acceptable ways of rationalising preferences, and reached conclusions that are consistent with EU.

The sets of explanations given for the independence violating preference pattern (b) (a') (N = 14) were:

(i) Treatment (b) was preferred over (a) because the risk of the 1% chance of death is not worth taking for the 10% chance of living for 18 years in full health, and (a') was preferred over (b') because the difference between a 10% and an 11% chance of a positive outcome is negligible, so one might as well choose the option that offers a chance of living for 18 years (N = 2).

(ii) Treatment (b) was preferred over (a) because the certainty of a positive outcome is an overriding factor, and (a') was preferred over (b') because the risk of the 1% chance of death is worth taking for the 10% chance of living for 18 years in full health (N = 2).

(iii) Treatment (b) was preferred over (a) because the certainty of a positive outcome is an overriding factor, and (a') was preferred over (b') because the difference between a 10% and an 11% chance of a positive outcome is negligible, so one might as well choose the option that offers a chance of living for 18 years (N = 3).

DISCUSSION

The sample sizes in the qualitative results are very small but they do give some indication for the reasons behind people's choices in the Allais contexts. Many of these reasons may have been easy to hypothesise, but it is necessary to obtain evidence in order to support hypotheses. For the three sets of qualitative explanations for the Allais paradox preference pattern (b) (a'), a different cognitive process is used to reach a preference for (b) than that used to reach a preference for (a'). It cannot be concluded that these cognitive processes are inconsistent. They are merely different.

What appeared to happen is that when the participants were asked to rate an option that gives a positive outcome for certain against an option that has a small probability of immediate death, they often focused upon the small probability of immediate death, which may have induced risk averse behaviour. With an identical difference in the percentage chance of immediate death between the two options, but with a large chance of death in both options, the participants often appeared to attach less weight to the probability of death and were more likely to base their preference on the option that gave the best possible outcome, which resulted in seemingly risk seeking behaviour. These explanations are consistent with both loss aversion and the overweighting of small probabilities. By increasing the probability of death in both treatment options across contexts, and thus by omitting certainty (and negating the certainty effect), the prominent attribute in the contexts switched, for many participants, from probability to outcome, which appears to explain at least some of the violations of independence.

Another important point to note is that in many of the money contexts that have been used to test for the Allais paradox, the options have been presented in a non-collapsed format, as explained earlier. In a non-collapsed format, it is not immediately obvious that the alternatives within a context share a common outcome, which may be used as an explanation as to why preference behaviour that is consistent with violations of independence has been observed. In the current study, the independence axiom was systematically violated even though the presentational design made it obvious that (a) and (b), and (a') and (b'), share a common outcome. Though it has been argued that the EU axioms would never be violated if they were presented in a clear and understandable manner,[32-34] many of the violations of independence reported in this paper appeared to be deliberate. These findings are consistent with those of Slovic and Tversky, who found that their participants generally did not change their preferences after hearing a counter-argument that conflicted with their initial choices in Allais-type contexts, irrespective of whether or not they initially conformed with the independence axiom.[7]

Concerning the test of consistency, there are many possible reasons why only 68.4% of the participants gave the same answer to the practice context as they did to the identical context in the main part of the experiment. For example, many of the participants may have been almost indifferent between the treatment options in these contexts and thus prone to change their preference, their preferences may have be highly transient, or some of them could have made errors, particularly in the practice contexts which they undertook at the beginning of the experiment. There is a possibility that the practice context may have influenced the answers to the repeated context. However, *a priori*, it was considered important by the author that the participants expressed that they fully understood the Allais-type practice context before completing the main questionnaire, as it was feared that, if given cold, some participants would be confused by the Allais contexts in their collapsed format. In hindsight, a similar but not identical context to those used in the Allais paradox test may have been more appropriate to use as the practice context.

As a further point relating to methodological design, it has recently been reported that pie charts are a poor format to use in both choice tasks, where participants are required to make simple larger/smaller judgements, and estimation tasks, where participants are required to make more precise evaluations.[35] Feldman-Stewart et al. found evidence to suggest that vertical bars, horizontal bars, numbers and systematic ovals are better than pie charts for choice tasks, and that numbers and systematic ovals are the best performers for estimation tasks.[35] The pie charts used in the experiment reported here were accompanied by numbers in terms of the percentage chance of surviving for x years, and thus it is assumed that the accuracy of the participants' perceptions of the outcomes and associated probabilities was satisfactory.

Given that descriptive violations of the EU axioms have often been reported, the modification of the standard gamble method to align with rank-dependent utility theory (RDU) has been suggested.[2] RDU generalises EU by weakening the independence axiom. An essential feature of RDU is that it assumes that people will apply decision weights to probabilities. For example, when people are faced with a treatment option that involves, say, a 1% chance of death, RDU specifies that they may apply a weight to the probability and perceive the chance of death as being

greater than 1%. It is important to note that RDU significantly deviates from EU only for gambles or treatments that involve small or large probabilities of outcomes, but it can incorporate the main patterns of probability transformation reported in the literature.[10,28-31] If RDU reflects preferences better than EU, an argument can be made to transform the probabilities derived from the standard gamble method for the purpose of eliciting utility measurements.

The axioms of RDU have been tested under risk and uncertainty in contexts using money outcomes, but the results have suggested that RDU may not offer a descriptive improvement on EU.[36-37] The theory has yet to be similarly tested in the context of health outcomes and, therefore, it is not known if an RDU-modified standard gamble method would be likely to improve approximations of health-related cardinal utility. It would thus be useful and interesting to test the underlying axioms of RDU and other generalisations of and alternatives to EU in the context of health outcomes.

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Table 1
Gambles demonstrating independence

	Probability		
	0.89	0.10	0.01
Gamble A	$1m	$5m	$0
Gamble B	$1m	$1m	$1m
Gamble A'	$0	$5m	$0
Gamble B'	$0	$1m	$1m

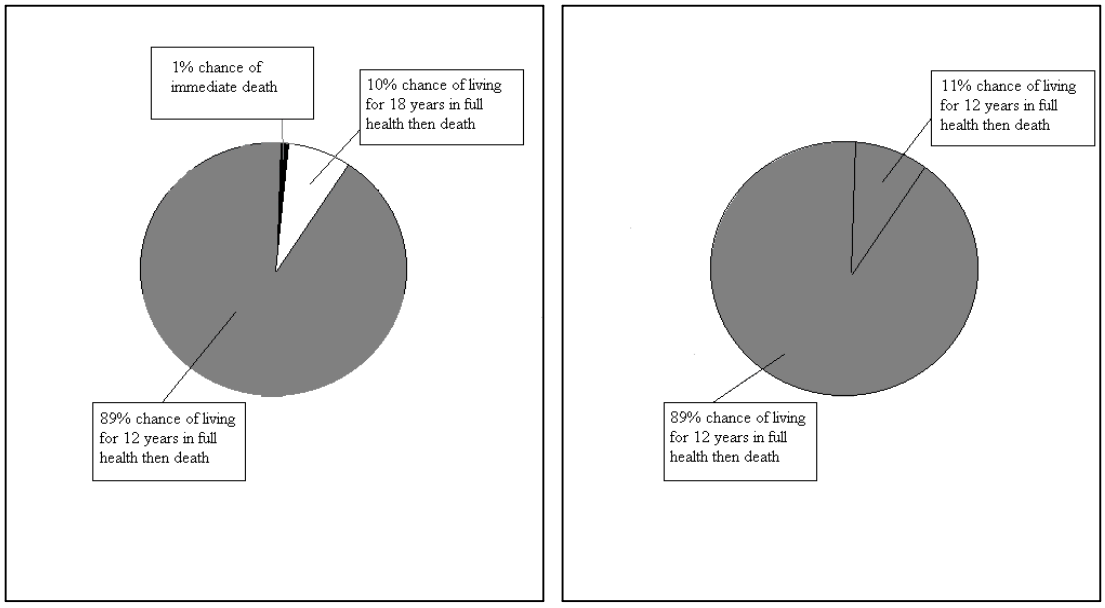
Table 2
Quantitative results from the test of the Allais paradox

Preference pattern	Number of participants
(a) (a')[a,b]	14 (36.8%)
(b) (b')	4 (10.5%)
(a) (b')	3 (7.9%)
(b) (a')[c]	14 (36.8%)
(a) (I')[d]	2 (5.3%)
(I) (a')	1 (2.6%)

[a]Preference pattern (a) (a') implies a preference for treatment (a) over (b) and (a') over (b'). All other preference patterns can be read similarly.
[b]Preference patterns (a) (a') and (b) (b') are independence conforming preference patterns. All others are independence violating preference patterns.
[c](b)(a') is the preference pattern predicted by the Allais paradox.
[d](I') implies indifference between (a') and (b'). (I) implies indifference between (a) and (b).

Imagine that you have an illness from which, without treatment, you will die almost immediately. Your doctor tells you that there are two alternative available treatments for your illness. The two pies drawn below represent the chances of certain outcomes from the two treatments, treatment (a) and treatment (b):

(a) (b)



Your doctor tells you that a new treatment is being developed for your illness. This new treatment would give you thirty years of full health followed by death, but will not be available for you. Please rate treatment (a) and treatment (b) on the scale below.

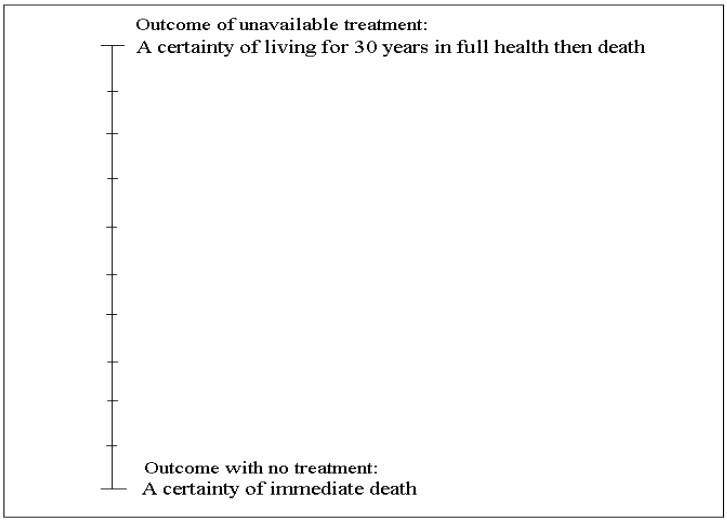
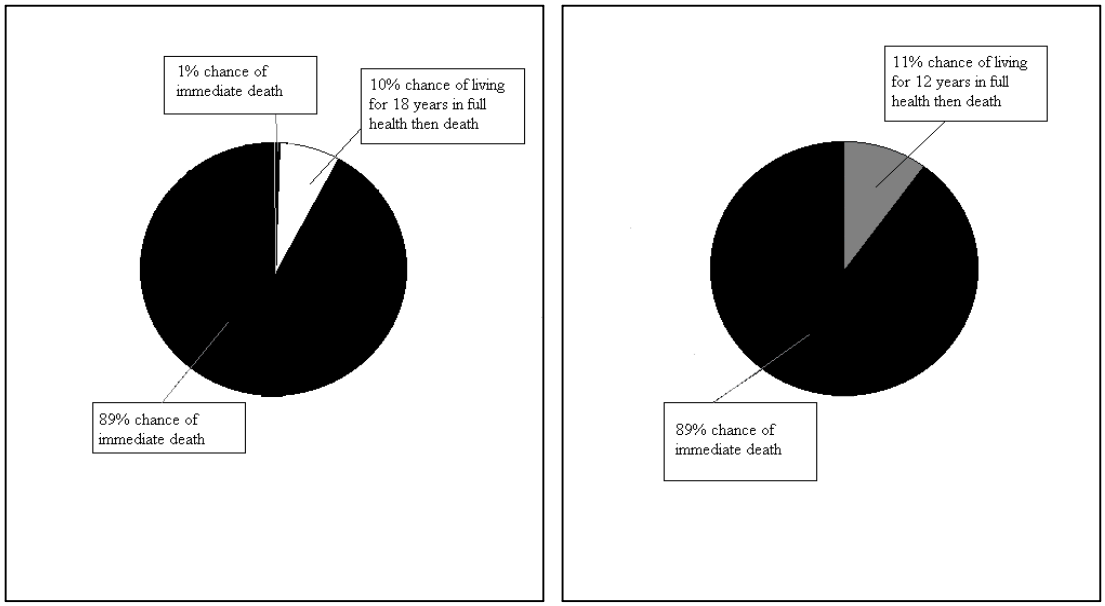


Fig. 1. The first context in the Allais-type test

Imagine that you have an illness from which, without treatment, you will die almost immediately. Your doctor tells you that there are two alternative available treatments for your illness. The two pies drawn below represent the chances of certain outcomes from the two treatments, treatment (a) and treatment (b):

(a) (b)



Your doctor tells you that a new treatment is being developed for your illness. This new treatment would give you thirty years of full health followed by death, but will not be available for you. Please rate treatment (a) and treatment (b) on the scale below.

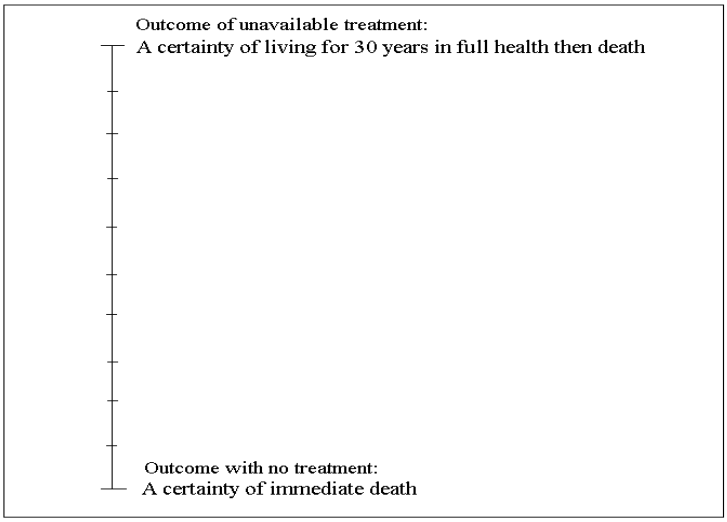


Fig. 2. The second context in the Allais-type test