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A survey analyzing assumptions for rational decision making in health care

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Abstract

The aim of this study was to investigate whether an introductory educational course on rational decision making is able to improve decisions about health and health care including decisions based on the quality-adjusted life year model. Specifically, this study analyzed the impact of the course on i) health preference reversals (PRs); ii) violations of the condition of mutual utility independence (MUI) between preferences for longevity and health status; and iii) violations of the independence axiom (IA) of expected utility theory. A total of 162 undergraduate students were randomly assigned to a pre- or post-educational group based on a pre-specified allocation sequence. In both groups students took a survey with choice and valuation exercises on health and longevity and made health decisions for themselves and for those for whom they are responsible. More than 70% of students without training demonstrated PRs. Yet, education did not significantly alter the number of PRs. The IA was violated in almost half of participants without training but significantly less so in the group receiving the educational intervention. Violations of MUI were found in 51% of participants without training with a non-significant change in the educational group. In this sample violations of conditions for rational choice in health care were common and only to a small degree amenable to education.

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1. Introduction

The neoclassical paradigm presupposes consumer sovereignty on the basis of fully informed and rational individuals, who maximize their expected utility. A basic assumption of rational choice theory is the principle of invariance (Tversky and Kahneman 1986): It stipulates that the relation of preference should not depend on the description of the options (description invariance) or the method of elicitation (procedural invariance) or, in short, framing effects. The principle of procedural invariance is violated by preference reversals (PRs). In PR experiments subjects are asked to choose between two lotteries. One lottery (or 'bet') in a pair typically has a high probability of winning a small amount of money and is called the probability bet or 'p bet'. The other, riskier lottery in the pair has a smaller chance of winning a larger amount of money and is called the dollar bet or '$ bet'. In addition to choosing between the gambles, in PR experiments subjects are asked to place a monetary value (certainty equivalent, CE) on gambles. A PR occurs when the preference revealed by choice is the reverse of the preference revealed by monetary valuation, e.g., when the chosen bet is given a lower valuation (Lichtenstein and Slovic 1971). In fact, in most experiments subjects have chosen the p bet due to risk aversion and assigned the higher price to the $ bet, but rarely have they chosen the $ bet and placed a higher value on the p bet (Cox and Grether 1996).

Lotteries such as the $ bet are not uncommon in health care. Consider, for example, a cancer drug yielding a survival curve with a long 'tail', reflecting a small probability of 'winning' a large number of life years. A patient deciding or starting to take this cancer drug thus faces a $-bet lottery.

Yet, the literature on testing for PRs in the valuation of health is sparse as was noted already a decade ago (Oliver and Sorenson 2008). Among the few studies that have been conducted since then (e.g., Weyler and Gandjour 2011, Oliver 2013a, b, and Pinto-Prades *et al*. 2018) is a survey by Oliver (2013b). It compared the occurrence of PRs in a personal frame with the occurrence in a social frame using a non-iterative elicitation approach. To this end, the study elicited choices and CEs from students taking the viewpoint of i) patients and ii) medical doctors making decisions on behalf of patients. In each role and choice/valuation exercise, students had the choice between two health lotteries as a result of avoiding death. The study showed that the social decision making context generated fewer preference patterns that were consistent with rational choice theory, although not statistically significantly fewer, and more predicted PRs with choice of the p bet and higher valuation of the $ bet (although the difference also did not reach statistical significance). Oliver attributed higher frequency of predicted PRs in the social frame to heightened risk aversion in the choice task, i.e., more respondents opting for the p bet because they were less willing to take a "'chance' with lives other than their own".

Our study used the questionnaire by Oliver (2013b) as a basis and extended it in various directions in order to address further questions. In particular, our study had the following aims: First, we broadened the study of rational decision making by investigating violations of the condition of mutual utility independence (MUI) between preferences for longevity and health status, a prerequisite for using the quality-adjusted life year (QALY) model. Second, we analyzed a possible violation of the independence axiom (IA) of expected utility theory (EUT). And third, we analyzed whether an introductory educational course on expected value and decision making under risk was able to reduce the occurrence of PRs as well as violations of MUI and IA. At the heart of

this study, the third goal tested a requirement for establishing consumer sovereignty in health care, viz., better education improves rational choice.

2. Theoretical Background

In the following, we present and discuss four axioms that participants of our survey needed to satisfy in order to comply with the requirements of the QALY model and EUT.

Axiom 1. Independence axiom (IA). Let A, B, and C be three lotteries with $A \succcurlyeq B$. If $pA + (1-p)C \succcurlyeq pB + (1-p)C$, then $\succcurlyeq$ satisfies the IA.

Axiom 2. Procedural invariance. Let A and B be two lotteries and let $\varsigma(\cdot)$ denote the price of a lottery. If $A \succcurlyeq B$ and $\varsigma(A) \succcurlyeq \varsigma(B)$, then $\succcurlyeq$ satisfies procedural invariance.

Axiom 3. Utility independence. Let longevity and health status be the two attributes Y and Z of the utility of lifetime health. If conditional preferences for lotteries on Y given Z do not depend on the particular level of Z, then attributes Y and Z satisfy utility independence (cf. Bleichrodt 1995).

Axiom 4. Mutual utility independence (MUI). If attribute Y is utility independent of Z and Z is utility independent of Y, then attributes Y and Z satisfy MUI (cf. Bleichrodt 1995).

IA (axiom 1) is one of the (von Neumann-Morgenstern) axioms that individuals need to satisfy in order to maximize expected utility under risk according to EUT (bearing in mind that EUT is widely considered to be the normative theory of decision making under risk). IA (axiom 1) can also be classified as a special case of axiom 4 if lotteries A and B in axiom 1 represent combinations of attributes Y and Z and lottery C is equal to zero. Furthermore, violations of the first and second axiom present violations of EUT that lead to PRs. Finally, while it may be possible to explain deviations from EUT including PRs by prospect theory (Kahneman and Tversky 1979) or the rank-dependent expected utility model (Quiggin 1982) (including variants thereof such as the dual model (Yaari 1987)), we did not test these theories because they were either not taught as such during the educational course (rank-dependent expected utility model) or were taught but not as a prescriptive model (prospect theory).

3. Methods

While Oliver (2013b) primarily enrolled postgraduate students in social policy from the London School of Economics, participants in our study differed particularly in two respects: first, with regard to their Alma mater and country of enrollment (Germany); and second, with regard to their study program (undergraduate program with a concentration in finance).

For details on the questionnaire by Oliver (2013b), which was used as a basis of our own questionnaire, we refer readers to the original publication. Our complete questionnaire was provided in English and had 16 items (see Appendix) including questions on age, gender, past education, and work experience. Following Oliver (2013b) our study elicited individual

preferences in a non-iterative fashion. In the following we describe the additional tests we undertook. To test for MUI in the personal decision-making frame we framed lotteries not only in terms of life years but also in terms of a specific health state. For this purpose, we considered chronic depression. Violation of MUI occurs when participants change their preference pattern compared to a healthy state. If the assumption of MUI is violated, the underlying reason might be a maximum endurable time (MET) (Bleichrodt 1995, and Weyler and Gandjour 2011). Therefore, we also tested for MET. To this end, we analyzed in what percentage of cases with violation of MUI a smaller CE was found when using chronic depression as a health state as opposed to using full health as a health state (e.g., based on questions 4) and 12.2) in the questionnaire). We compared this rate with the chance rate, which is 50%. We also investigated – as a subgroup analysis - the rate of MET in MUI violations among participants who fulfilled the criteria for a past depression based on the Patient Health Questionnaire-2 (PHQ-2) (Kroenke *et al*. 2003). For the PHQ-2 we used a cutoff score of 3 to define past depression (Kroenke *et al*. 2003).

In order to test for IA, we compared choices between a monthly and a yearly timeframe from the viewpoint of patients. In the monthly timeframe we multiplied all options by $p \approx 0.1$ compared to the yearly timeframe. That is, we mixed all options with the lottery (0, 0.9). We checked whether participants maintained the same preference order as compared to presenting the options independently of that lottery. That is, we determined the percentage of participants who changed their preference pattern when moving from a yearly to a monthly timeframe. Note that IA can also be classified as a type of MUI axiom where preferences for health status are independent of preferences for longevity. In this case, satisfaction of MUI can be interpreted as a rational response, bearing in mind that violation of MUI may also be interpreted as 'rational' in case of MET.

To test whether an introductory educational course is able to reduce deviations from rational choice, we randomly assigned students to an education and a control group based on a pre-specified allocation sequence (block randomization). This helped to ensure an equal allocation of participants. The content of the educational course consisted of two 3-hour lectures on decision making under risk including expected value calculation and expected utility theory. It included a brief introduction to the axioms of expected utility theory including IA. The lecture did not refer to a health care setting or specifically address PRs (because knowledge on expected value calculation is already sufficient to avoid PRs in the questionnaire). In the education group the questionnaire was filled in after completion of the lectures while in the control group it was filled in before. Students in the control group were instructed not to share information on the questionnaire with the education group.

Based on the responses and in agreement with Oliver (2013b), a total of eight preference pattern was discerned. We considered p-values below 0.05 to be statistically significant.

4. Results

4.1. Pre-education survey

A total of 73 students were allocated to receive no education and thus participated in the pre-education survey. Six questionnaires were excluded due to non-response or nonsensical answers. Characteristics of study participants are described in Table I.

Table I: Characteristics of survey participants.

	Pre-education	Post-education
Average age (years)	19.56	19.38
Gender		
Male	77.61%	81.48%
Female	22.39%	18.52%
Average experience as a trainee (months)	5.12	4.66
Average experience as a full-time employee (months)	3.73	1.28
University-level education (months)	2.83	2.35
Participants with depression symptoms (score ≥ 3) based on the Patient Health Questionnaire (PHQ-2)	29.85%	30.86%

A summary of the results is presented in Table II. The notation follows Oliver (2013b). The preference pattern P$ indicates that the p bet was chosen in the choice task but that the $ bet was valued higher when eliciting the CE. All other preference patterns can be read similarly. Furthermore, 'I' denotes indifference in the choice question and '=' denotes the elicitation of equal CEs in the valuation questions. The preference patterns P$ and $P are combined under the term 'strict' PR in the following.

Table II: Results of the pre-education survey.

Preference pattern	Number of observations	Interpretation
Personal decision-making frame (yearly framework)		
$$	5 (7.46%)	Consistent with rational choice theory
PP	14 (20.9%)	Consistent with rational choice theory
P$	12 (17.91%)	Predicted preference reversal
$P	26 (38.8%)	Unpredicted preference reversal
I$	3 (4.48%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	0	Weak unpredicted reversal
$=	7 (10.45%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory

Social decision-making (yearly framework)		
$$	3 (4.48%)	Consistent with rational choice theory
PP	18 (26.87%)	Consistent with rational choice theory
P$	20 (29.85%)	Predicted preference reversal
$P	17 (25.37%)	Unpredicted preference reversal
I$	4 (5.97%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	2 (2.98%)	Weak unpredicted reversal
$=	3 (4.48%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory
Personal decision-making frame (monthly framework)		
$$	6 (8.95%)	Consistent with rational choice theory
PP	18 (26.87%)	Consistent with rational choice theory
P$	12 (17.91%)	Predicted preference reversal
$P	31 (46.27%)	Unpredicted preference reversal
I$	0	Weak predicted reversal
P=	0	Weak predicted reversal
IP	0	Weak unpredicted reversal
$=	0	Weak unpredicted reversal
I=	0	Consistent with rational choice theory
Personal decision-making frame (yearly framework, chronic depression)		
$$	20 (29.85%)	Consistent with rational choice theory
PP	3 (4.48%)	Consistent with rational choice theory
P$	18 (26.87%)	Predicted preference reversal
$P	7 (10.45%)	Unpredicted preference reversal
I$	11 (16.42%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	2 (2.98%)	Weak unpredicted reversal
$=	6 (8.95%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory

In personal decision making 72% of respondents were inconsistent with rational choice theory, i.e., demonstrated PRs. In social decision making the percentage was not significantly different (69%, $p = 0.70$). In personal decision making strict PRs were significant in the unpredicted versus the predicted direction at the 1% level (n = 12, 26: $\chi^2(1) = 10.32 > \chi^2_{0.01}(1) = 6.63$). In the social decision making frame, strict PRs were not significantly different between a predicted and unpredicted direction (n = 20, 17: $\chi^2(1) = 0.4865 < \chi^2_{0.05}(1) = 3.84$). Yet, compared to the personal

context, in the social decision making context the rate of predicted PRs was significantly higher (n = 12, 20: $\chi^2(1) = 4 > \chi^2_{0.05}(1) = 3.84$).

Using a shorter time span in personal decision making, 49% of respondents changed their preference pattern compared to a yearly timeframe ($p < 0.0001$), thus violating IA. Using a state of chronic depression, 51% of participants changed their preference pattern ($p < 0.0001$), thus violating MUI. Among patients with MUI violation, the occurrence of MET was increased but not significantly so ($p = 0.2$).

On the other hand, using chronic depression as a health state led to fewer inconsistencies with rational choice theory (a decrease to 66%, $p = 0.59$). This was also the case for participants who exceeded the cut-off score for PHQ-2 (65%, $p = 0.68$).

4.2.Post-education survey

Eighty-nine students were allocated to the educational intervention and thus participated in the post-education survey. Eight questionnaires were excluded due to non-response or nonsensical answers.

Results are shown in Table III. Compared to the personal context, the number of predicted PRs in the social decision making context was not significantly increased (n = 25, 17: $\chi^2(1) = 3.047 < \chi^2_{0.05}(1) = 3.84$). Education did not significantly alter the number of PRs both in the personal and social decision making context (p-values are 0.62 and 0.95, respectively). Education also did not significantly alter violations of MUI ($p = 0.55$). Only IA was significantly less violated in the group receiving the educational intervention ($p = 0.019$).

Table III: Results of the post-education survey.

Preference pattern	Number of observations	Interpretation
Personal decision-making frame (yearly framework)		
$$	4 (4.94%)	Consistent with rational choice theory
PP	16 (19.75%)	Consistent with rational choice theory
P$	17 (20.99%)	Predicted preference reversal
$P	34 (41.98%)	Unpredicted preference reversal
I$	1 (1.23%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	2 (2.47%)	Weak unpredicted reversal
$=	7 (8.64%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory
Social decision-making (yearly framework)		

$$	4 (4.94%)	Consistent with rational choice theory
PP	21 (25.93%)	Consistent with rational choice theory
P$	25 (30.86%)	Predicted preference reversal
$P	17 (20.99%)	Unpredicted preference reversal
I$	6 (7.4%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	2 (2.47%)	Weak unpredicted reversal
$=	6 (7.4%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory
Personal decision-making frame (monthly framework)		
$$	7 (8.64%)	Consistent with rational choice theory
PP	17 (20.99%)	Consistent with rational choice theory
P$	21 (25.93%)	Predicted preference reversal
$P	35 (43.2%)	Unpredicted preference reversal
I$	1 (1.23%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	0	Weak unpredicted reversal
$=	0	Weak unpredicted reversal
I=	0	Consistent with rational choice theory
Personal decision-making frame (yearly framework, chronic depression)		
$$	12 (14.81%)	Consistent with rational choice theory
PP	6 (7.4%)	Consistent with rational choice theory
P$	24 (29.63%)	Predicted preference reversal
$P	17 (20.99%)	Unpredicted preference reversal
I$	14 (17.28%)	Weak predicted reversal
P=	0	Weak predicted reversal
IP	4 (4.94%)	Weak unpredicted reversal
$=	4 (4.94%)	Weak unpredicted reversal
I=	0	Consistent with rational choice theory

5. Discussion

In this study the majority of respondents made choices that were inconsistent with the principle of invariance rooted in rational choice theory, thus confirming an earlier finding by Oliver (2013b). In the study by Oliver (2013b) the social decision making context generated fewer preference patterns that were consistent with rational choice theory, although not statistically significantly

fewer, and more predicted PRs (although the difference also did not reach statistical significance). Our study confirms the increase in predicted PRs in the social decision making frame, which even reaches statistical significance. This means that participants were more risk averse when they had to decide for other people's lives.

In addition, we show that an introductory course on expected utility theory failed to reduce the occurrence of PRs. Moreover, we find evidence for considerable violations of IA and MUI assumptions. As there is a trend towards increased rates of MET in MUI violations for depressive health states, MUI violation may still be interpreted as a 'rational' response to a depressive health state. In addition, using chronic depression as a health state led to fewer inconsistencies with rational choice theory. Perhaps using a disease state as opposed to a healthy state, forced students to think more thoroughly through the choices, a facilitator that in the study by Oliver (2013b) had been hypothesized for financial incentives but failed to be confirmed. The finding of a more rational response should also alleviate concerns regarding the imaginability of a depressive state in individuals without prior experience of depression. In agreement with our study, previous studies had demonstrated the ability of individuals without prior experience of depression to imagine depressive states under risk (Pyne *et al*. 2009, and Weyler and Gandjour 2011).

As a limitation, we acknowledge that potential alternatives to reducing PRs exist and may involve the elicitation of repeated choices (Loomes and Pogrebna 2016) with or without additional education. However, the approach of implementing repeated choices needs to be balanced against decision fatigue. In addition, in health care patients typically face one-off decisions, as exemplified by the case of a cancer drug provided in the introduction. Therefore, it is unclear how the approach of eliciting repeated choices would be compatible with real-world conditions.

In sum, this study shows considerable violations of rationality principles that are largely unaffected by education. While our study is comprehensive in testing various rationality assumptions underlying consumer sovereignty in health care within one survey, it is limited by testing only one particular health scenario and only one group of 'health consumers'. That is, concerns regarding generalizability of findings from a specific student population to other ages and educational backgrounds remain. Still, our results are biased in favor of a lack of responsiveness to educational measures as bachelor students majoring in business and finance seem to be particularly suited for learning rationality concepts. Therefore, the results add to existing concerns about establishing consumer sovereignty in health care (Sirgy *et al*. 2011).

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