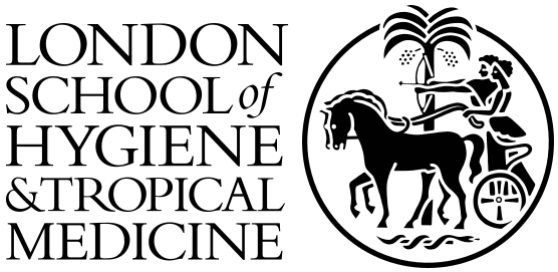

Assessing Rationality in Discrete Choice Experiments in Health: An Investigation into the Use of Dominance Tests

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Highlights

i. What is already known about the topic?

Dominance tests are often applied to test for the rationality of choice behavior of discrete choice experiment (DCE) participants. Some researchers use them to exclude participants failing the test.

ii. What does the paper add to existing knowledge?

Although dominance tests are frequently applied in DCEs, there is no consensus on how to account for them in data analysis and interpretation. In many cases the number of participants failing the test is lower than what is predicted by random utility theory.

iii. What insights does the paper provide for informing health care-related decision making?

Computing the proportion of participants that are expected to fail the dominance test and comparing that with the observed proportion can give indication of DCE study quality.

Abstract

Introduction: Dominance tests are often applied to test for the rationality in the choice behavior of discrete choice experiment (DCE) participants. This study examines how dominance tests have been implemented in recent DCE applications in health, and discusses their theoretical and empirical interpretation.

Methods: Health-related DCEs published in 2015 were reviewed for the inclusion of tests on choice behavior. For studies that implemented a dominance test, information on application and interpretation of the test was extracted. Authors were contacted for test choice sets and observed proportions of subjects who chose the dominated option. Coefficients corresponding to the choice set were extracted to estimate the expected probability of choosing the dominated option with a logistic model, and compared with the observed proportion. The theoretical range of expected probabilities of possible dominance tests was calculated.

Results: Of 112 health related DCEs, 49% included at least one test for choice behavior; 28 studies (25%) included a dominance test. The proportion of subjects in each study that chose the dominated option ranged from 0% to 21%. In 46% of studies, the dominance test led to the exclusion of participants. In the 15 choice sets that were analyzed, two had larger proportions of participants choosing the dominated option than expected ($p<0.05$).

Conclusion: Although dominance tests are frequently applied in DCEs, there is no consensus on how to account for them in data analysis and interpretation. Comparison of expected and observed proportions of participants failing the test might be indicative of DCE quality.

Introduction

Discrete choice experiments (DCE) are used in health care decision-making to elicit the stated preferences of stakeholders (e.g., patients and clinicians) on the attributes of treatments and other health care goods and services [1-3]. The use of DCEs in health-related topics has steadily increased over the years [1]. Their importance for health policy decision making is highlighted by the recent regulatory interest in their usefulness for capturing patient preferences on treatment benefit-risk trade-offs [4, 5].

DCEs are founded on Lancaster's theory of consumer behavior [6] and commonly analyze choice data with McFadden's Random Utility Model (RUM) [7]. The theory of consumer behavior assumes that the participants are utility-maximizing agents and are willing to trade off between attributes in the choice experiment. Accordingly, stated preferences captured by DCEs should conform with axioms of rational choice, such as completeness, transitivity, and monotonicity [8]. Different ways to identify DCE subjects whose choice behavior violates common rationality axioms have been proposed in the literature [2]. The most frequently applied test in DCEs has been the dominance test [1] where, given researchers' *a priori* assumptions on attribute level ordering, one of the choice alternatives is clearly superior. Participants who choose the dominated alternative are considered to have failed the test. These participants may not have understood the choice task, may not have paid sufficient attention to it, or may have been exhibiting non-rational choice behavior.

In many studies, participants who fail the dominance test are excluded from final data analysis [9-12]. However, this interpretation of the dominance test is challenged by the fact that a certain proportion of participants are expected to 'fail' the dominance test because of the probabilistic property of the RUM [13]. That is, the RUM includes an error component which can be interpreted in various ways that can account for the seemingly irrational behavior. First, this might result from measurement error—the subjects understand the task, attend to the questions appropriately, but make a mistake and answer the dominated choice question incorrectly. Given this, their responses to other questions may still reflect their true, rational preferences. Second, this might result from unobserved variables—the participants might infer additional information on attribute value beyond what is presented in the DCE. For instance, they may infer a higher quality of care from the cost of care. This leads to choice behavior that is seemingly not in

line with the researchers' *a priori* expectations of what is rational behavior, but when the additional information is taken into account, the participants are actually choosing according to the axioms of rationality [14], and thus most of their preference data is likely to be useful for the analysis.

This paper aims at understanding how dominance tests can and should be used for supporting choice validity assessment in DCEs, with a focus on the health domain. Past reviews of DCEs in health have surveyed the frequency of use of dominance and other rationality tests [1-3]. Our contribution surveys dominance tests in the literature in more depth, to assess how authors have used dominance tests, and to analyze whether the test results have been interpreted in line with what the RUM predicts.

Methods

Data Source

DCE studies published in 2015 were identified from a systematic review on how qualitative methods have been used to support health DCEs [15]. The year of 2015 was chosen because it reflects recent use of dominance tests, and was expected to cover a wide spectrum of current applications. The papers were reviewed for general study characteristics including sample type, area of application (as defined by de Bekker-Grob et al [2]), form of application (categories of self-completion and personal interview), funding of the study, context of country (defined by the World Bank classification of high, middle, or low income countries [16]), the application of choice behavior tests (defined by a review of methodological studies [17]), and whether a pilot study has been conducted.

From the 126 DCE papers published in 2015 [15], 112 elicited preferences and reported empirical data. Eleven studies focused on the development of DCEs, rather than the elicited preferences, and were excluded. Another two studies were excluded as their preference elicitation method did not include choices between multiple profiles. Two studies presented the same DCE, and one of them was excluded to avoid double counting. Table 1 provides an overview of the extracted study characteristics.

For the 28 studies reporting the use of the dominance test, data on application and interpretation of the test were extracted, including the levels of the attributes used for the design of the dominant and dominated choice

alternatives, the observed proportion of respondents choosing the dominated option, the authors' reasoning for the use of dominance test, how authors dealt with participants who 'failed' the dominance test, and the conclusions that the researchers drew from the test. Because this information was not provided in the papers, all authors were contacted with a request for this information. Fourteen (50%) authors responded and provided the requested data. Because one of the studies included two separate DCEs, the analysis was conducted on 15 DCEs.

Calculations

The expected probability of passing the dominance test was computed for the studies for which data were available using a logit model. This model assumes that the individual respondent's (n) utility (u) towards a specific choice option (j) is a function of the measured utility (v) of the presented attribute levels (X_{nj}) and an unexplainable error component (ε_{nj}),

$$u_{nj} = v_{ij}(X_{nj}\beta) + \varepsilon_{nj}, \qquad \text{Equation 1}$$

where ε_{nj} are independently and identically distributed (following a Gumbel distribution with a location η and a scale $\mu > 0$). Then, in a two choice alternative setting, the probability that choice alternative *j* is chosen over choice alternative *i* is:

$$P_{ij} = \frac{\exp(X'_{nj}\beta)}{\exp(X'_{nj}\beta)+\exp(X'_{ni}\beta)}. \qquad \text{Equation 2}$$

The expected probability of choosing the dominated alternative (p_e) is estimated using Equation 2 with the attribute levels set to reflect those of the choices in the dominance test. The theoretical range of expected probabilities of possible dominance tests is $p_e min - p_e max$. The $p_e\ max$ is derived from the hypothetical dominance test with the largest expected probability of choosing the dominated alternative, i.e. with the smallest possible utility difference between the dominant and dominated alternatives given the estimated β and levels X_{nj}. Similarly, $p_e min$ is derived from the hypothetical dominance test with the smallest expected probability of choosing the dominated alternative (see Figure 1). Both $p_e min$ and $p_e max$ are normally <50% and the range they span necessarily includes p_e.

The observed number of participants choosing a dominated option was divided by the total number of participants to calculate the observed proportion of participants choosing the dominated option. A z-test was conducted to assess whether the observed proportion (p_o) was equal to the calculated expected probability of choosing the dominated option (p_e). A test statistic with p≤0.05 was considered significant. All calculations were done using Microsoft Excel 2013. The extractions and calculations were quality controlled by a second member of the study team.

Results

The dominance test was the most frequently reported test of choice behavior, applied in 28 studies (25%) (Table 1). The studies with dominance tests were comparable to the studies without dominance tests in terms of 'area of application,' 'country of application,' 'application form,' and whether a pilot study had been conducted (Table 1). However, the sample-type varied between the studies; studies that employed the dominance test were significantly more frequently undertaken with patients (Pearson's $\chi^2 = 7.13$, p<0.01).

In the 28 studies with a dominance test, the study authors used a range of terminology to refer to it: a control measure, or a consistency-, validity-, internal validity-, logic- or rationality-test. The most frequently expressed reason for including a test was concern about the participants' understanding of the choice task (8 studies, 29%); second was concern about participants lacking attention (4 studies, 14%), and third was to test for rationality (3 studies, 11%). In 46% of the studies, the dominance test led to the exclusion of participants, either based on a single dominance test or a combination of tests. Ten studies (36%) tested the effects of participant exclusion on the model, and in all instances, the model was not sensitive to participant exclusion. The dominance tests in three of the 28 studies resulted from the generation of the choice sets as part of the experimental design, and therefore were not intentionally designed [18-20].

In the 14 studies that provided additional data, the proportion of subjects choosing the dominated option (p_o) ranged from 0% to 21% (Figure 2). Most of the studies had low p_o with only a single study with $p_o > 10\%$. Neither of the choice alternatives in the dominance test choice set for this study was dominant. Expected probabilities (p_e) based on the dominated choice sets ranged from 0% to 49%. Of the 14 choice sets analyzed, in seven (50%) the observed proportion was smaller than the expected probability ($p_o < p_e$, p<0.05), while in five studies (36%) the observed

proportion was equal to the expected probability (p>0.05). In the remaining two sets (14%), the observed proportion of participants that chose the dominated option was found to be larger than the expected probability ($p_o > p_e$, p<0.05). Details on calculations of the expected probabilities and z-test for equality between the expected probability of choosing the dominated option and observed proportion are included in the Supplemental Material.

The minimum expected probabilities ($p_e min$,), or the probability that the dominated option was chosen when the two choice sets would have the largest difference between the levels of all alternatives, were low for all but two studies (15% and 49%) [18, 21]. The first one of these ($p_e min = 15\%$) used labeled choice sets where the levels were linked to the alternative labels and constrained the possible choice sets. The second one ($p_e min = 49\%$) had highly insignificant utility estimates. The maximum expected probabilities ($p_e max$), or the probability that the dominated option was chosen when the two choice sets would have the smallest difference between the levels of all alternatives, were close to 50% for all but one study, which had two dominance questions [22] and the test was counted as passed only if both questions were answered correctly.

Discussion

Interpretation of the dominance test question differs considerably in the literature. Although some authors describe the dominance test as a test for rationality, most presented the dominance test as a test for participants' understanding of the survey, and their attentiveness to it. Inattention or lack of understanding is a challenge in all internet-based surveys [23]; their identification is vital because random responses increase the answer variability, resulting in greater uncertainty in utility model parameter estimates [24]. However, exclusion of participants is problematic for three reasons. First, it might introduce bias as participants choosing the dominated option may not be random in the study population. For instance, they might have lower health literacy or numeracy skills. Second, even though the exclusion may increase internal validity of the experiment, it also decreases the experiment's external validity [25]. Third, the RUM error term allows to account for the seemingly irrational behavior when $p_o \leq p_e$. Intuitively, $p_o > p_e$ might seem a good criterion to decide whether participants choosing the dominated option should be excluded from the sample. However, uncertainty in the utility estimates influences the minimum expected share of participants choosing the dominated option – the lower the utility estimates are, the higher the $p_e min$ is.

Therefore, if the DCE is designed inappropriately and results in low utility estimates, $p_e > p_e min$ is necessarily high and provides little information on the proportion of participants that could be expected to choose the dominated alternative.

A low p_e with $p_o < p_e$ could potentially serve as an indicator of a good study design, as it requires (i) a low $p_e \min(< p_e)$ (i.e., that the resulting utility estimates are high), (ii) participants' understanding of the dominance test's level ordering is similar to the authors' *a priori* expectations, (iii) the dominance test has a single clearly dominating alternative (which together with (i) and (ii) leads to a low p_e), and $p_o < p_e$. In only two of the 14 examined studies [22, 26] p_o was larger than p_e. Implications of $p_o > p_e$ depend on the magnitude of p_e:

- Very low p_e (as in the study of Marshall et al [22]), points towards a well-designed DCE, including the dominated choice test—although the participants are choosing the dominated alternative more often than what RUM predicts, it is unlikely to be due to systematic misunderstanding of the attribute and level definitions, given that the utility estimates are high (leading to low $p_e min$). However, as $p_o > p_e$, this suggests that the participants are not attending to the dominated choice task, although they are answering the other DCE questions consistently (given low p_e).

- Higher p_e (and necessarily p_o), as in the study of Ngosuraches and Thongkeaw [26], may be indicative of flawed design of either the study itself (if $p_e min$ is high), or of the dominated choice question (if $p_e min$ is low but p_e is high).

As more and more DCEs are conducted and applied in the health domain [1], there is an increasing focus on the validity of the results [27] and consequently need for greater consistency in the application and interpretation of dominance tests. Although we agree with Lancsar and Louviere [13] that a dominance test should not be used as a simple binary criterion for excluding participants from the analysis set, we believe the metrics introduced in this paper, $p_e min$, p_e and p_o, give useful information about quality of the study design and have potential to serve as a standardized way to interpret dominance test results. As such, we believe dominance tests are a useful addition to analyst's toolbox and augment the information that can be obtained on participants' behavior with other tests such as assessing for lexicographic preferences (choosing based on single attribute only) and time to complete survey.

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Figures and Tables

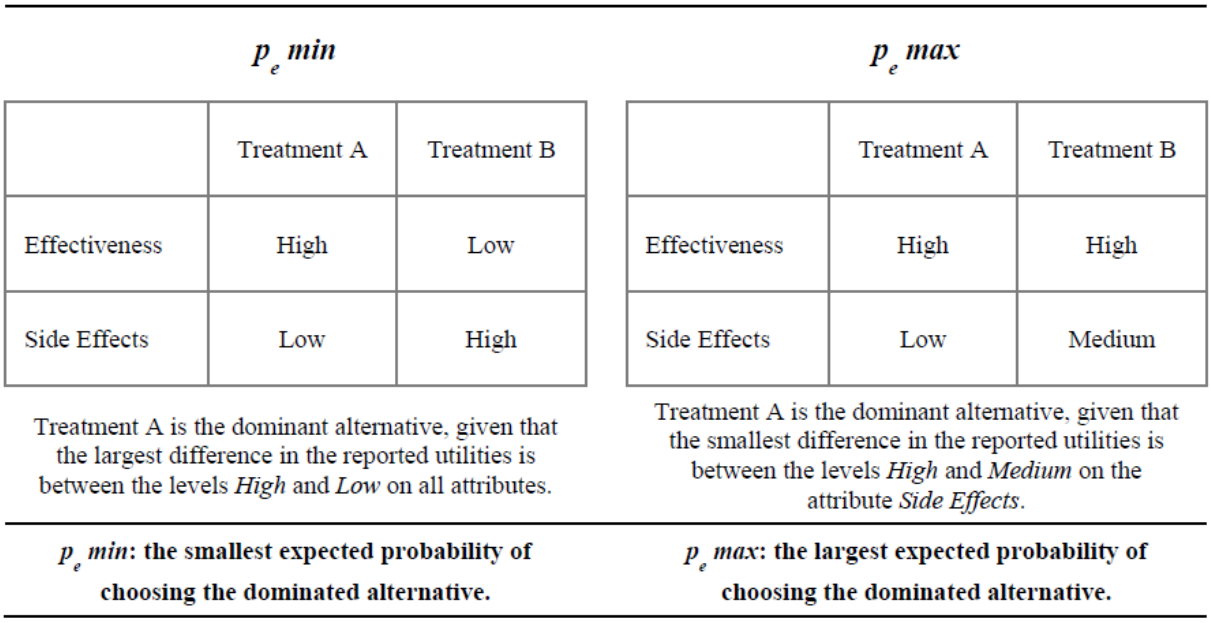

Figure 1. Depiction of hypothetical dominance sets with the smallest and largest expected probabilities.

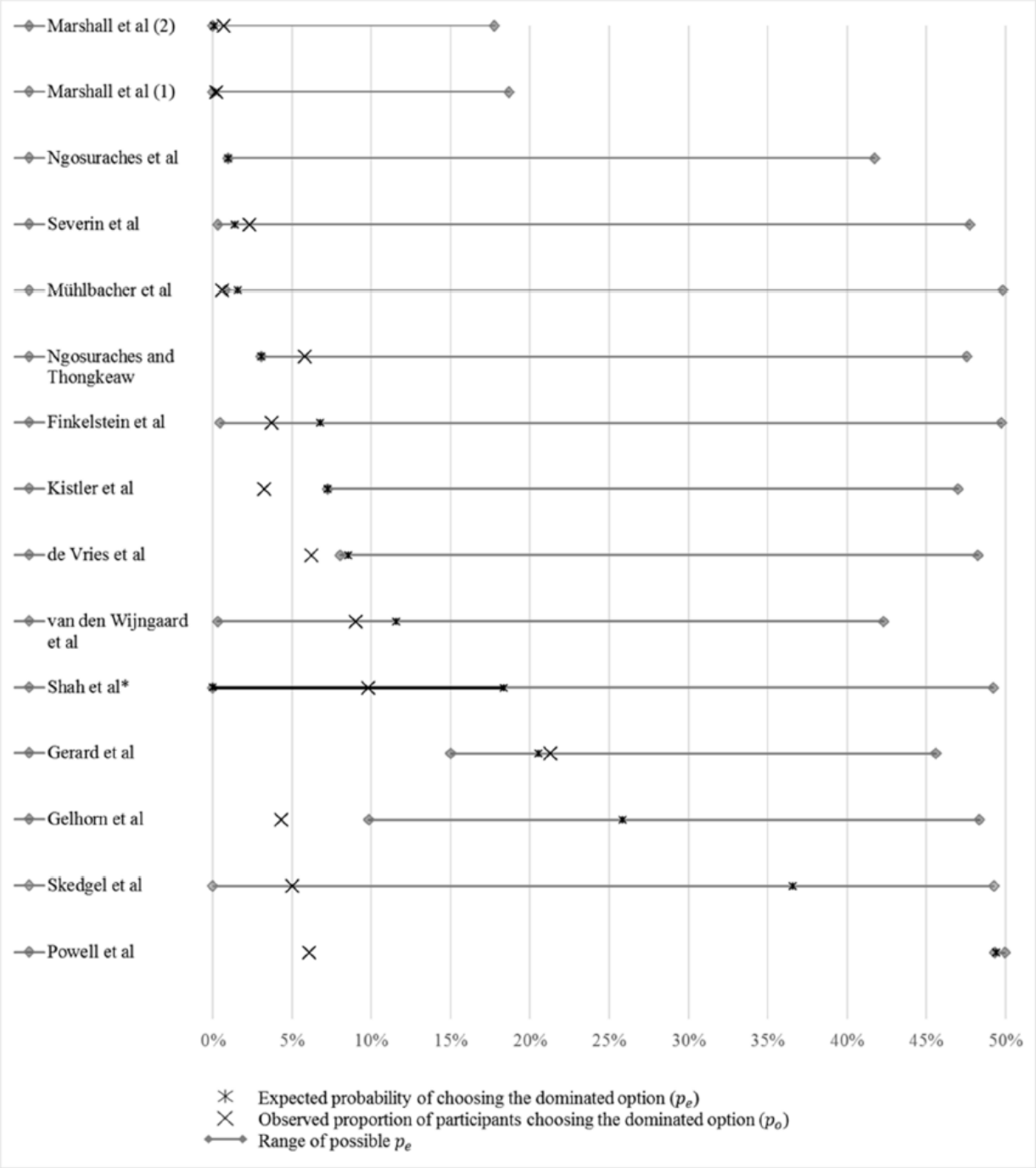

Figure 2. Predicted probabilities with their possible ranges, and the observed proportions of participants choosing the dominated option.

* Shah et al. study had various dominated choice questions, for which the range of p_e is indicated with the bold line.

Table 1. Overview of study characteristics and choice behavior tests for all DCE studies and for those with and without dominance test.

	All studies	**Incl. dominance**	**Excl. dominance**
	% (n)	**% (n)**	**% (n)**
Area of application from De Bekker-Grob et al [2] *	n=112	n=28	n=84
Patient or consumer experience factors	34% (38)	25% (7)	37% (31)
Valuing health outcomes	8% (9)	7% (2)	8% (7)
Investigating trade-offs	25% (28)	43% (12)	19% (16)
Estimating utility weights within the QALY framework	8% (9)	4% (1)	10% (8)
Job choices	7% (8)	4% (1)	8% (7)
Developing priority setting mechanism	9% (10)	11% (3)	8% (7)
Health professionals' preferences	9% (10)	11% (3)	8% (7)
Other	7% (8)	4% (1)	7% (6)
Sample type*			
Patient	42% (47)	64% (18)	35% (29)
Health worker	21% (23)	18% (5)	21% (18)
General public	42% (47)	32% (9)	45% (38)
Decision maker	5% (6)	4% (1)	6% (5)
Application form			
Personal interview	24% (27)	25% (7)	24% (20)
Self-completed	70% (78)	68% (19)	70% (59)
Unknown	6% (7)	7% (2)	6% (5)

	All studies % (n)	Incl. dominance % (n)	Excl. dominance % (n)
Country of application			
High income	80% (90)	82% (23)	80% (67)
Low/middle income	18% (20)	18% (5)	18% (15)
Mixed	2% (2)	0% (0)	2% (2)
Funding			
(Pharmaceutical-) Industry	26% (29)	29% (8)	25% (21)
University	21% (23)	18% (5)	21% (18)
Government	39% (44)	39% (11)	39% (33)
Non-governmental organization	14% (16)	14% (4)	14% (12)
Pilot test			
Included a pilot test	60% (67)	57% (16)	61% (51)
Choice behavior test*			
Dominance	25% (28)	100% (28)	0% (0)
Sen	1% (1)	0% (0)	1% (1)
Transitivity	1% (1)	4% (1)	0% (0)
Stability	16% (18)	21% (6)	14% (12)
Task non-attendance	12% (13)	7% (2)	13% (11)
Level recoding	2% (2)	4% (1)	1% (1)
Compensatory tests	8% (9)	14% (4)	6% (5)

*The categories of 'area of application', 'sample type' and 'choice behavior test' are not mutually exclusive

Table 2. Implementation and interpretation of dominance tests.

	Study		Dominance Tests		
DCE	**Source**	n	p_o	**Exclusion**	**Sensitivity**
Beulen et al	[28]	893	0.0%		x
Chamot et al	[29]	208	4.8%		
Chen et al	[9]	98	2.0%	x	
Cross et al	[30]	614	-		x
de Vries et al	[10]	161	6.2%	x	x
Finkelstein et al	[11]	542	3.7%	x	
Gelhorn et al	[12]	245	4.3%	x	
Gerard et al	[21]	451	21.3%		
Howard et al[a]	[31]	662	-		x
Kistler et al	[32]	277	3.2%	x	
Kromer et al	[33]	200	-		
Krucien et al	[34]	150	4.0%		
Lock et al	[35]	133	2.0%		
Marshall et al (1)[b]	[22]	1775	0.2%	x	
Marshall et al (2)[b]	[22]	449	0.7%	x	
Morillas et al	[36]	355	7.0%	x	
Mühlbacher et al	[37]	683	0.6%	x	
Nafees et al	[38]	415	1.2%	x	
Ngorsuraches et al	[39]	314	-	x	

	Study		Dominance Tests		
DCE	**Source**	n	p_o	**Exclusion**	**Sensitivity**
Ngorsuraches and Thongkeaw	[26]	155	5.8%	x	
Powell et al	[18]	82	6.1%		x
Robyn et al	[19]	351	2.8%		x
Rosato et al	[40]	155	1.9%	x	
Severin et al	[41]	608	2.3%	x	x
Shah et al	[20]	3969	9.8%		x
Skedgel et al	[42]	656	5.0%		
Tinelli et al	[43]	692	10.0%		x
van de Wetering et al	[44]	1205	-		
van den Wijngaard et al	[45]	93	9.0%		x

[a] Howard et al included the dominance test in the pilot, not in the main study.

[b] Two DCEs in one publication

n, number of study participants; p_o, observed proportion failing the test; Exclusion, participants excluded from the analysis; Sensitivity, sensitivity analysis including and excluding participants

Assessing Rationality in Discrete Choice Experiments in Health: An Investigation into the Use of Dominance Tests

Supplement 1. Empirical investigation of the dominance test: calculations of the expected probabilities and z-tests for equality between the expected probability of choosing the dominated option and observed proportion

		Observed dominated choices	**Expected probability and z-test**		**Hypothetical test scenarios**		**Consequences**	
DCE	***n***	p_o(%)	p_e(%)	**z-test**	$p_e max$(%)	$p_e min$(%)	**Exclusion**	**Sensitivity Analysis**
de Vries et al [1]	161	6.2	8.6	n.s.	48.3	8.0	x	x
Finkelstein et al [2]	542	3.7	6.8	-2.86*	49.8	0.5	x	
Gelhorn et al [3]	245	4.3	25.8	-7.70*	48.4	9.8	x	
Gerard et al [4]	451	21.3	20.5	n.s.	45.6	15.0		
Kistler et al [5]	277	3.2	7.2	-2.56*	47.0	7.2	x	
Marshall et al (1)[a] [6]	1775	0.2	0.0–0.2[b,d]	n.s.	18.7	0.0	x	
Marshall et al (2)[a] [6]	449	0.7	0.0–0.1[b,d]	4.64*	17.8	0.0	x	
Mühlbacher et al [7]	683	0.6	1.5	-2.04*	49.8	0.8	x	
Ngorsuraches et al [8]	314	-	1.0	-	41.7	1.0	x	

Ngorsuraches and Thongkeaw [9]	155	5.8	3.1	1.97*	47.6	3.1	x	
Powell et al [10]	82	6.1	49.4	-7.85*	49.9	49.3		x
Severin et al [11]	608	2.3	1.4	n.s.	47.8	0.3	x	x
Shah et al [12]	3969	9.8	0.0–18.3[b]	-13.89*	49.2	0.0		x
Skedgel et al [13]	656	5.0	36.6	-16.80*	49.3	0.0		
van den Wijngaard et al [14]	93	9.0	11.6[c]	n.s.	42.3	0.3		x

*The test statistic was considered significant if $p \leq 0.05$.

[a] Two DCEs in one publication

[b] Not every participant was given the same dominance choice question. This is the range of possible p_e depending on the question that the person saw; the highest p_e was used for the z-test.

[c] Dominance test passed, if one of two dominance questions was answered correctly.

[d] Dominance test passed, if both dominance questions were answered correctly.

n, number of participants; n_o, observed number choosing the dominated option; p_o, observed proportion choosing the dominated option; p_e, expected probability of choosing the dominated option; p_e max, largest probability of choosing the dominated option; p_e min, smallest probability of choosing the dominated option.

Note: The studies that excluded participants, and those that did a sensitivity analysis are indicated by the two columns on the right.

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