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Deploying projected utility to predict health behaviour in health economics: a quantitative study

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Expected utility is increasingly deployed as a predictor of health behaviour within the broader domain of health economics and health sciences in general. However, research shows that this concept only explains limited variance in health behaviour. This limited explained variance is often attributed to the questionable theoretical axioms underlying the concept. Due to these limitations it was hypothesised that the concept of utility should not be conceptualized in terms of preferences for future health states (expected utility), but as realistic approximations of future health states (projected utility). Therefore, this study examines whether deployment of projected utility separately or in combination with expected utility enhances predictions of health behaviour as compared to expected utility. Online questionnaires were disseminated among a nationally representative panel of Dutch citizens (*N* = 2,550). The questionnaire encompassed items capturing demographic characteristics alongside instruments measuring expected utility, projected utility and health behaviour. Data analysis entailed descriptive, reliability, validity and model statistics. The results suggest that projected utility has a larger significant direct effect on and explains more variance in health behaviour than expected utility. The results subsequently indicate that expected utility and projected utility combined have a larger significant direct effect on and explain more variance in health behaviour than each type of utility separately. Health economists, policy makers and other public health practitioners are well advised to at least consider the separate or even combined deployment of projected utility in health economics in order to enhance predictions of health behaviour.

Keywords Expected utility, Projected utility, Health behaviour, Health preferences, Health beliefs

Since the early 1970 s expected utility has been deployed in health economic evaluation in order to value health states[1]. Expected utility in health economic evaluation denotes a quantified measure of preference for a specific health outcome expressed on a cardinal scale where 1.0 signifies perfect health, 0.0 represents death and values below zero indicate health states considered worse than death[2,3]. Although traditionally rooted in health economic evaluation, the concept of expected utility has increasingly found resonance within the broader domain of health economics and health sciences in general, where it is now being employed with growing frequency to predict different types of health behaviour[4–8]. However, a number of pertinent concerns may be raised regarding the predictive value of expected utility when employed in such a context as research shows that expected utility only explains limited variance in health behaviour[4–8]. Several authors have pointed out that this may be due to the scientifically ambiguous and questionable theoretical axioms underlying the concept of expected utility, which can only be accepted under particular conditions, making expected utility an imperfect predictor of health behaviour[9–12]. These authors argue that expected utility can only be an accurate predictor of health behaviour if health preferences are established based on complete information, while research suggests that people are incapable of gathering and comprehending all possible information[9,10]. Such authors also suggest that expected utility can only be an accurate predictor of health behaviour if health preferences are established based on absolute rationality, while research shows that people have a tendency to decide and act on bounded rationality[9,11]. They further indicate that expected utility can only be an accurate predictor of health behaviour if health preferences are stable over time, while research indicates that people are inclined to reconsider their health preferences over time when new choice options are introduced[9,12]. In order to account for these apparent theoretical limitations it has been hypothesised by the apparent critics and detractors of expected utility that

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it might be more in concurrence with current scientific literature to not conceptualize utility in terms of an individual's hypothetical preference for future health states (expected utility), but instead reconceptualize it in terms of an individual's realistic approximation of future health states (projected utility)[13]. Although prior research has compared the practical, theoretical and methodological merits of deploying novel utility types in health economics[13], no definitive endeavours have been mounted in order to empirically measure projected utility, let alone deploy it as a predictor of health behaviour in health economics. Therefore, this study sets out to examine whether the deployment of projected utility or a combination of projected utility and expected utility in health economics enhances the prediction of health behaviour as compared to the conventional deployment of expected utility. The findings of this study may contribute to legitimising and substantiating an alternative conceptualisation of utility in the context of predicting health behaviour. This might provide health economists, policymakers, public health practitioners and other pertinent stakeholders with a more robust and well-substantiated foundation for developing and evaluating (cost-)effective health behavioural interventions or policies enabling more informed, judicious and evidence-based policy decision-making in the health domain.

Methods

Design, participants and procedures

In this study a quantitative research approach involving questionnaires was utilized. The questionnaires were disseminated online to a large panel of Dutch citizens curated by the IPSOS research agency. Panel members were invited via email and supplied with all requisite information accompanied by a formal request for informed consent. Inclusion was limited to those panel members who provided consent for their responses to be utilised in subsequent research. The data collected for this study was gathered during the period of September to December 2021. The questionnaires that were distributed to the panel members contained various items related to sample characteristics followed by multiple measurement instruments on expected utility, projected utility and health behaviour.

Questionnaire, scales and items

Sample characteristics were reported using items on 'age', 'gender', 'health status', 'living area', 'residential region', 'education level' and 'annual income'. Either ordinal scales with ascending response categories or nominal scales with dichotomous response categories were used to measure these items. Expected utility was discerned using the EQ-5D-5L instrument combined with the time-trade-off method as both are commonly deployed for valuing health states in health economics[14–16]. The EQ-5D-5L instrument is comprised of five dimensions including 'mobility', 'self-care', 'usual activities', 'pain and discomfort' and 'anxiety and depression' (Supplementary material 1)[14–16]. A 5-point scale was used to measure these dimensions yielding generic health state profiles to which standard expected utility values were ascribed based on an extensive time-trade-off valuation study conducted among the Dutch population[17,18]. These time-trade-off studies derive expected utility values by eliciting individuals' preferences regarding the amount of remaining life expectancy they are willing to forgo in order to avoid persisting in a suboptimal health state[19,20]. Projected utility was assessed using the Subjective Health Experience (SHE) ladders, which are ladder-shaped visual analogue scales developed by Bloem and Stalpers to measure how individuals expect to function physically and mentally while pursuing a life aligned with their goals within real-world constraints[21–24]. The SHE ladders were used to evaluate expected utility regarding 'physical health', 'psychological health', 'social health' and 'general health' for the upcoming month (Supplementary material 1)[21–24]. An 11-level ladder scale in which level 0 represented an estimation of the worst day of upcoming month and level 11 represented an estimation of the best day of upcoming month was deployed to determine scores[21–24]. Health behaviour was assessed using a newly developed and validated instrument grounded in the five health behaviour dimensions that emerged from the BRAVO@Work project[25,26]. This instrument encompasses these five dimensions, namely 'exercise', 'nutrition', 'rest', 'smoking' and 'alcohol use' alongside an overarching dimension regarding 'general health' that captures aspects of health behaviour not addressed by the specific items (Supplementary material 1)[25,26]. A 6-point Likert scale ranging from 1 = fully disagree to 6 = fully agree was deployed to measure these dimensions[25,26].

Analysis, interpretation and software

Sample characteristics were examined employing descriptive statistics. Categorical variables were conveyed as percentages, whereas continuous variables were presented as means. Questionnaire characteristics were assessed through measures of construct reliability, construct validity, convergent validity and discriminant validity. Construct reliability was appraised using Cronbach's alpha (α), rho_a and rho_c coefficients, which are considered satisfactory when their values exceed the 0.70 threshold[27]. Construct validity was determined by executing a factor analysis in which the instruments' factorial structure was verified and refined by excluding redundant and cross-loading items[27]. Convergent validity was assessed by computing the average variance extracted (AVE) coefficient, which is regarded as adequate when its value surpasses the 0.50 threshold[27]. Discriminant validity was evaluated through the heterotrait-monotrait (HTMT) ratio, which was considered acceptable when it remained below the 0.90 threshold[27]. Model characteristics were investigated through the construction of regression models and were delineated using effect sizes, significance levels and explained variance[27]. Effect sizes of associations between model variables were examined via standardised Beta coefficients (β), which were interpreted as small when below 0.30, moderate when between 0.30 and 0.50 and substantial when exceeding the 0.50 threshold[27]. Significance levels of these associations was assessed using p-values, which are considered significant when falling below the 0.05 threshold[27]. Explained variance was reported through R-squared (R^2) coefficients, which can be deemed small when below 0.30, moderate when between 0.30 and 0.50 and substantial when surpassing the 0.50 threshold[27]. Sample characteristics were derived by utilising the IBM

SPSS Statistics software package Version 27, whereas questionnaire and model characteristics were extracted employing the SmartPLS software package Version 4.0[27,28].

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and the prevailing ethical laws, regulations and guidelines of the Netherlands, all of which are integrated into the research protocols and panel management practices of IPSOS research agency. IPSOS research agency also complies with the ICC/ESOMAR International Code on Market, Opinion and Social Research and Data Analytics as well as the ESOMAR Data Protection Checklist. IPSOS research agency further holds ISO 20252:2019 and ISO 27001 certifications. According to the Dutch Central Committee on Research Involving Human Subjects (https://www.ccmo.nl/onderzoekers/wet-en-regelgeving-voor-medisch-wetenschappelijk-onderzoek/uw-onderzoek-wmo-plichtig-of-niet) and the Dutch Medical Research Involving Human Subjects Act (https://wetten.overheid.nl/BWBR0009408/2022-07-01) ethical approval was not required for this study as it does not constitute medical-scientific research nor does it subject participants to procedures or impose behavioural obligations. All participants provided written informed consent in accordance with the privacy policy of IPSOS research agency (https://www.ipsosisay.com/nl-nl/privacy-policy).

Results

Sample characteristics

The final sample for this study consisted of 2,550 panel members. The final sample was found to closely mirror the Dutch general population across key demographic and socio-economic indicators including 'age', 'gender', 'health status', 'residential region', 'education level' and 'annual income'[29–35]. Nevertheless, the final sample also reflected a population with a comparatively higher degree of urbanisation than that of the Dutch general population[29–35]. An overview of the sample characteristics is presented in Table 1.

Questionnaire characteristics

The instruments assessing projected utility (α = 0.88; rho_a = 0.89; rho_c = 0.92) and health behaviour (α = 0.72; rho_a = 0.79; rho_c = 0.82) could be considered reliable as all reported reliability coefficients exceeded the minimal threshold of 0.70. The projected utility instrument demonstrated adequate construct validity with all items loading onto a single factor, while the health behaviour instrument likewise exhibited sufficient construct validity following the removal of two items (i.e., 'smoking' and 'alcohol use'). The instruments for projected utility (AVE = 0.74) and health behaviour (AVE = 0.54) further evidenced satisfactory convergent validity as the average variance extracted surpassed the minimal threshold of 0.50. Discriminant validity was confirmed among the instruments for expected utility and projected utility (HTMT = 0.63), expected utility and health behaviour (HTMT = 0.53) and projected utility and health behaviour (HTMT = 0.73) with all heterotrait-monotrait ratios falling below the maximum acceptable value of 0.90. Given that the expected utility instrument comprises individual utility values and is not multidimensional, reliability and convergent validity could not be assessed. Nevertheless, in light of the aforementioned metrics, the measurement instruments employed in this study could be regarded as both valid and reliable.

Model characteristics

Three regression models were developed to investigate whether the use of projected utility or a combination of projected and expected utility improves the prediction of health behaviour in health economics compared to the traditional use of expected utility alone. For clarity and ease of understanding, only the general regression models are presented as segmenting by available control variables (e.g., age, gender, health status) yielded minimal additional insights apart from a few minor deviations.

Expected utility and health behaviour

The initial regression model explores the effect and explained variance of expected utility regarding health behaviour (Fig. 1). This first regression model shows that expected utility (β = 0.50, p <.01) has a significant and

Variables				
Age	$\bar{x}$ 49.3 years (18–89 years)			
Gender	48.6% male	51.4% female		
Health status	37.2% healthy	27.9% 1 disease	34.9% comorbidities	
Living area	56.8% city	34.3% suburb	8.9% rural	
Residential region	10.1% North Netherlands	21.1% East Netherlands	48.1% West Netherlands	20.7% South Netherlands
Education level	31.5% low	29.3% average	38.9% higher	0.4% unknown
Annual income	35.2% < €36.500	35.8% €36.500 – €73.000	14.6% > €73.000	14.4% unknown
Measures				
SHE	M = 6.86 (SD = 1.64)			
EQ-5D-5L	M = 1.57 (SD = 0.64)			
BRAVO	M = 4.26 (SD = 0.89)			

Table 1. Sample description.

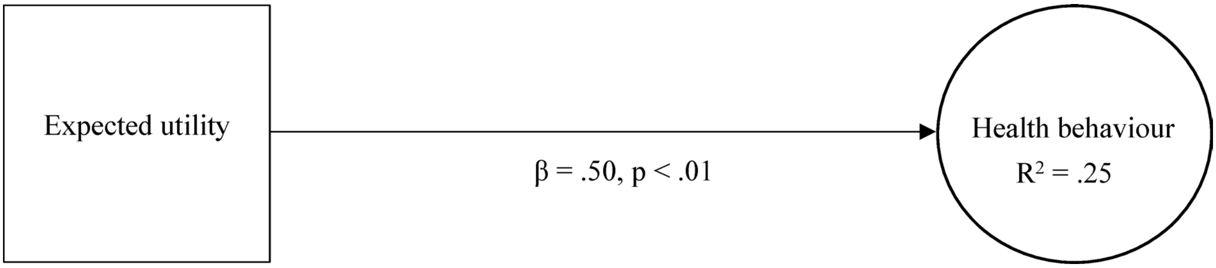

Fig. 1. Expected utility and health behaviour.

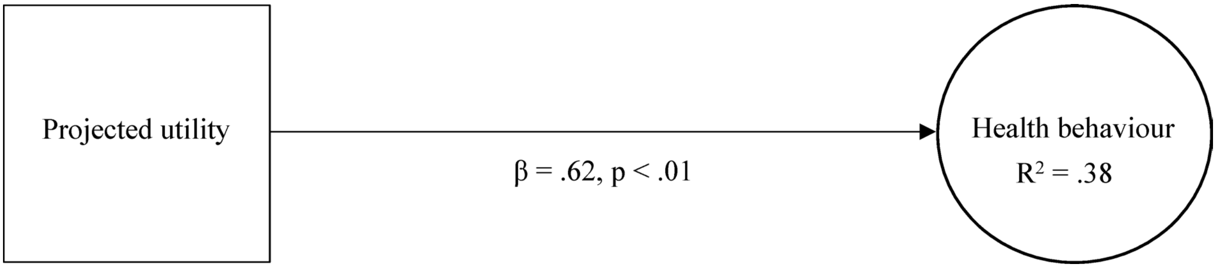

Fig. 2. Projected utility and health behaviour.

relatively strong direct effect on health behaviour indicating reasonable predictive power. This regression model further suggests that expected utility accounts for only limited variance in health behaviour ($R^2 = 0.25$).

Projected utility and health behaviour
The subsequent regression model examines the effect and explained variance of projected utility regarding health behaviour (Fig. 2). This second regression model shows that projected utility ($\beta = 0.62$, $p < .01$) also has a significant and even stronger direct effect on health behaviour than expected utility giving it considerable predictive power. This regression model further suggests that projected utility explains more variance in health behaviour ($R^2 = 0.38$) than expected utility.

Expected utility, projected utility and health behaviour
The last regression model examines the combined effect and explained variance of expected utility and projected utility regarding health behaviour (Fig. 3). This third regression model shows that the combined direct effect of expected utility ($\beta = 0.20$, $p < .01$) and projected utility ($\beta = 0.50$, $p < .01$) is significant and stronger than each type of utility separately providing this combination with even more predictive power. This regression model also shows that expected utility and projected utility combined explain more variance in health behaviour ($R^2 = 0.41$) than each type of utility separately.

Discussion
This study examines whether the deployment of projected utility or a combination of projected utility and expected utility in health economics enhances the prediction of health behaviour as compared to the conventional deployment of expected utility. The results suggest that projected utility has a larger significant direct effect on and explains more variance in health behaviour than expected utility. The results subsequently indicate that expected utility and projected utility combined have a larger significant direct effect on and explain more variance in health behaviour than each type of utility separately.

The enhanced predictive power of projected utility regarding health behaviour compared to expected utility could be explained through several conceptual perspectives. From an informational perspective[9,10], expected utility relies on a fully informed assessment of all possible health behaviours, whereas projected utility incorporates personal biases, assumptions and beliefs about health behaviours and their consequences rendering it a more contextually accurate predictor of real-world health behaviour. From a rationalist perspective[9,11], expected utility demands a perfectly rational evaluation of and trade-off between all possible health behaviours, whereas projected utility encapsulates the experience-based, disposition-driven and context depended judgments of health behaviours and their consequences rendering it a more precise reflection of real-world health behaviour. From a preference stability perspective[9,12], expected utility depends on unchangeable and temporally-consistent preferences for particular health behaviours, whereas projected utility incorporates anticipatory adaptation in preferences for particular health behaviours offering a more accurate reflection of real-world health behaviour. By respecting and incorporating the assumptions of incomplete information, bounded rationality and unstable preferences, projected utility may be regarded as a more discerning and context-sensitive predictor of health behaviour within the broader discipline of health economics and the health sciences in general.

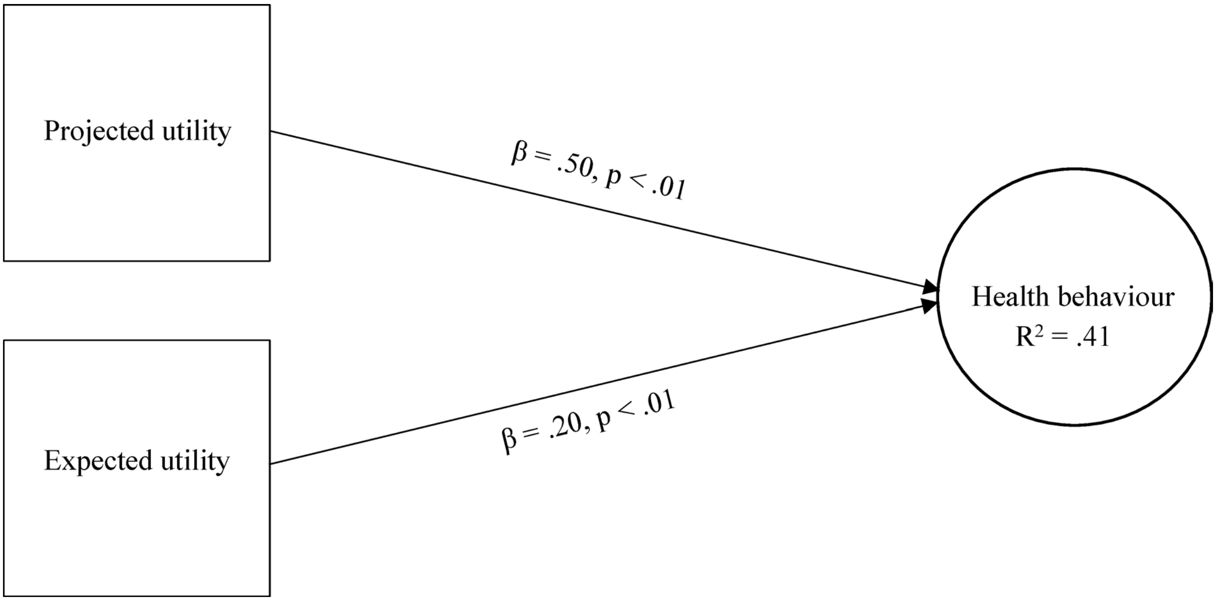

Fig. 3. Expected utility, projected utility and health behaviour.

Although not many have combined both expected utility and projected utility in order to determine health behaviour, this study shows that such a combined approach has enhanced predictive power regarding health behaviour relative to each type of utility separately. However, it should be remarked that the explained variance in health behaviour only increases marginally between the unilateral deployment of projected utility and the combination of expected utility and projected utility. One might suggest that this small increase in explained variance could be due to the artificial inflation of the R^2 statistic as it does not correct for the number of variables in the regression model[36]. One might also suggest that such a small increase in explained variance does not justify the efforts and transactional costs resulting from the complex measurement and deployment of both expected utility and projected utility[37,38]. One might even suggest that the use of expected utility and projected utility combined is not theoretically sound as they are both a representation of the same concept albeit conceptualized and measured in different ways. Due to these methodological, practical and theoretical drawbacks health economists, policy makers and other public health practitioners should carefully ponder whether using both types of utility combined provides sufficient added value.

Strengths and limitations

For this study several strengths and limitations can be identified. The first important strength of this study is that it constitutes one of the first attempts at conceptualizing, operationalizing and measuring projected utility. The second important strength of this study is the considerable sample size that has been established in order to generate relatively valid and reliable results. The third important strength of this study pertains to the valid and reliable measurement instruments used in order to produce accurate and veracious findings. The first limitation of this study relates to the potential bias towards relatively highly urbanized respondents within the used sample and the subsequent findings. The second limitation of this study is concerned with the limited generalizability of the findings due to the exclusively Dutch population and context of this research.

Practical implications

The results of this study have multiple implications for health economic practice and research. The results of this study imply that the current operationalization and measurement of expected utility in the context of health economics might not be the most accurate or precise. This observation further implies that alternative operationalizations and measures for expected utility (e.g., projected utility) might warrant more investigation and deserve more consideration in the field of health economics. Moreover, the results of this study especially suggest that projected utility may constitute such a viable alternative operationalization and measurement of expected utility.

Future research

The findings of this study prompt multiple directions for future research that may be worth pursuing. A first important direction for future research relates to repeating this research in disease-specific populations in order to understand its applicability in different patient groups. The second important direction for future research is concerned with repeating this study in different countries and regions in order to enhance interpretability and generalizability of the results. The third important direction for future research relates to explicating the process and associated transactional costs of measuring projected utility separately or in combination with expected utility.

Conclusion

Given the findings of this study, it has become evident that the expected utility conventionally deployed in health economics is not necessarily the most accurate predictor of health behaviour. In contrast, its less conventional counterpart, also known as projected utility, seems to be a considerable improvement with regard to the prediction of health behaviour. Additionally, the use of both concepts combined in order to predict health behaviour might be even more accurate. However, the combined use of both concepts may have some substantial methodological, practical and theoretical drawbacks that need to be considered. Nevertheless, health economists, policy makers and other public health practitioners are well advised to at least consider the separate or combined deployment of projected utility in health economics.

Data availability

The dataset used during this study is not publicly available, but is available from the corresponding author upon reasonable request.

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References

1. Devlin, N. J. & Brooks, R. EQ-5D and the EuroQol group: past, present and future. *Appl. Health. Econ. Health. Policy*. **15** (2), 127–137. https://doi.org/10.1007/s40258-017-0310-5 (2017).
2. Wolowacz, S. E. et al. Estimating Health-State utility for economic models in clinical studies: an ISPOR good research practices task force report. *Value Health*. **19**, 704–719. https://doi.org/10.1016/j.jval.2016.06.001 (2016).
3. Broekharst, D. S. E. et al. Rethinking the eidos, genos and diaphora of the health utility concept: a psychological perspective. *Front. Psychol.* **14**, 1–9. https://doi.org/10.3389/fpsyg.2023.1139931 (2023).
4. Dolman, M. & Chase, J. Comparison between the health belief model and subjective expected utility theory: predicting incontinence prevention behaviour in postpartum women. *J. Eval. Clin. Pract.* **2** (3), 217–222. https://doi.org/10.1111/j.1365-2753.1996.tb00048.x (1996).
5. Hellinger, F. J. Expected utility theory and risky choices with health outcomes. *Med. Care*. **27** (3), 273–279. https://doi.org/10.1097/00005650-198903000-00005 (1989).
6. van der Pligt, J. & De Vries, N. K. Expectancy-Value models of health behaviour: the role of salience and anticipated affect. *Psychol. Health*. **13** (2), 289–305. https://doi.org/10.1080/08870449808406752 (1998).
7. Jonas, K. Expectancy-value models of health behaviour: an analysis by conjoint measurement. *Eur. J. Social Psychol.* **23** (2), 167–183. https://doi.org/10.1002/ejsp.2420230205 (1993).
8. Cohen, D. R. Utility model of preventive behaviour. *J. Epidemiol. Commun. Health*. **38** (1), 61–65. https://doi.org/10.1136/jech.38.1.61 (1984).
9. Broekharst, D. S. E. et al. Measuring experienced utility in the context of health economic evaluation: A narrative overview. *Health Sci. Rep.* **8** (5), e70754. https://doi.org/10.1002/hsr2.70754 (2025).
10. Gonzalez Sepulveda, J. M., Johnson, F. R. & Marshall, D. A. Incomplete information and irrelevant attributes in stated-preference values for health interventions. *Health Econ.* **30** (11), 2637–2648. https://doi.org/10.1002/hec.4406 (2021).
11. McCaughey, D. & Bruning, N. S. Rationality versus reality: the challenges of evidence-based decision making for health policy makers. *Implement. Sci.* **5** (1), 39. https://doi.org/10.1186/1748-5908-5-39 (2010).
12. Jansen, S. J. et al. Unstable preferences: a shift in valuation or an effect of the elicitation procedure? *Med. Decis. Making: Int. J. Soc. Med. Decis. Mak.* **20** (1), 62–71. https://doi.org/10.1177/0272989X0002000108 (2000).
13. Broekharst, D. S. E., Bloem, S., Groenland, E. A. G., Jeurissen, P. P. T. & van Agthoven, M. Deploying the substitutive and complementary approaches to enhance predictions of health behaviour in health economics: A quantitative study. *Healthc. (Basel Switzerland)*. **13** (9), 1007. https://doi.org/10.3390/healthcare13091007 (2025).
14. Thompson, A. J. & Turner, A. J. A comparison of the EQ-5D-3L and EQ-5D-5L. *Pharmacoeconomics* **38**, 575–591. https://doi.org/10.1007/s40273-020-00893-8 (2020).
15. Devlin, N. J. & Brooks, R. EQ-5D and the EuroQol group: past, present and future. *Appl. Health Econ. Health Policy*. **15**, 127–137. https://doi.org/10.1007/s40258-017-0310-5 (2017).
16. Brazier, J. E. et al. Future directions in valuing benefits for estimating qalys: is time up for the EQ-5D? *Value Health*. **22**, 62–68. https://doi.org/10.1016/j.jval.2018.12.001 (2019).
17. Versteegh, M. M. et al. Dutch tariff for the Five-Level version of EQ-5D. *Value Health*. **19**, 343–352. https://doi.org/10.1016/j.jval.2016.01.003 (2016).
18. EuroQol, V. sets. (2025). https://euroqol.org/information-and-support/resources/value-sets/, (accessed 17 July).
19. Lugnér, A. K. & Krabbe, P. F. M. An overview of the time trade-off method: concept, foundation, and the evaluation of distorting factors in putting a value on health. *Expert Rev. Pharmacoecon Outcomes Res.* **20**, 331–342. https://doi.org/10.1080/14737167.2020.1779062 (2020).
20. Attema, A. E. et al. Time trade-off: one methodology, different methods. *Eur. J. Health Econ.* **14**, 53–64. https://doi.org/10.1007/s10198-013-0508-x (2013).
21. Bloem, J. G. & Stalpers, J. Subjective experienced health as a driver of health care behavior. *Nyenrode Res. Pap Ser.* **12**, 1–19. https://doi.org/10.2139/ssrn.2102513 (2012).
22. Bloem, J. G. *Experience as a Medicine: the Development of a General Subjective Health Instrument – in Dutch with English Summary* (Nyenrode Business University, 2008).
23. Stalpers, J. *Psychological Determinants of Subjective Health* (Nyenrode Business University, 2009).
24. Bloem, J. G. et al. Segmentation of health-care consumers: psychological determinants of subjective health and other person-related variables. *BMC Health Serv. Res.* **20**, 1–12. https://doi.org/10.1186/s12913-020-05560-4 (2020).
25. Peeters, M. C. W. et al. BRAVO op Het werk: Een Onderzoek Naar de relatie Tussen Leefstijlgedragingen En individuele werkprestatie. *J. Hum. Factors*. **40**, 5–9 (2015).
26. Wierenga, D., Engbers, L. H. & van Empelen, P. The design of a real-time formative evaluation of the implementation process of lifestyle interventions at two worksites using a 7-step strategy (BRAVO@Work). *BMC Public. Health*. **12**, 619. https://doi.org/10.1186/1471-2458-12-619 (2012).
27. Hair, J. F. et al. When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* **31**, 2–24. https://doi.org/10.1108/EBR-11-2018-0203 (2019).
28. Bala, J. & Contribution of SPSS in Social Sciences Research. *Int. J. Adv. Res. Comput. Sci. Softw. Eng.* **7** 250–254. https://doi.org/10.26483/ijarcs.v7i6.2773. (2016).
29. CBS, Age distribution. https://www.cbs.nl/en-gb/visualisations/dashboard-population/age/age-distribution, (2024). (accessed 3 February).

30. RIVM, Bevolking | Bevolkingsomvang | Leeftijd En Geslacht. https://www.vzinfo.nl/bevolking-bevolkingsomvang-leeftijd-en-geslacht#:~:text=De%20verhouding%20tussen%20mannen%20en,worden%20(51%2C3%25), (2024). (accessed 3 February).
31. RIVM. Chronische aandoeningen en multimorbiditeit. https://www.vzinfo.nl/chronische-aandoeningen-en-multimorbiditeit/leeftijd-en-geslacht#:~:text=5%2C7%20miljoen%20mensen%20met,ten%20minste%20%C3%A9%C3%A9n%20chronische%20ziekte, 2024 (accessed 3 February).
32. CBS. What is the level of education in the Netherlands? (2024). https://longreads.cbs.nl/the-netherlands-in-numbers-2024/what-is-the-level-of-education-in-the-netherlands/, (accessed 3 February).
33. PBL, De stad verbeeld. (2024). https://www.pbl.nl/sites/default/files/downloads/PBL_2015_De_stad_verbeeld_1744.pdf, (accessed 3 February).
34. CBS, Inwoners per gemeente. https://www.cbs.nl/nl-nl/visualisaties/dashboard-bevolking/regionaal/inwoners, (2024). (accessed 3 February).
35. CBS. Income distribution (standardised income). (2024). https://www.cbs.nl/en-gb/visualisations/income-distribution, (accessed 3 February).
36. Rencher, A. C. & Pun, F. C. Inflation of R2 in best subset regression. *Technometrics* **22**, 49–53. https://doi.org/10.1080/00401706.1980.10486100 (1980).
37. Riewpaiboon, A. Measurement of costs for health economic evaluation. *J. Med. Assoc. Thail.* **97**, 17–26 (2014).
38. Krauth, C. et al. Empirical standard costs for health economic evaluation in Germany–a proposal by the working group methods in health economic evaluation. *Gesundheitswesen* **67**, 736–746. https://doi.org/10.1055/s-2005-858698 (2005).

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Author contributions
D.S.E.B. wrote the manuscript. D.S.E.B., S.B. and E.A.G.G. analysed and interpreted the data. D.S.E.B. and S.B. were involved in the data collection. D.S.E.B., S.B., E.A.G.G., P.P.T.J. and M.A. reviewed and edited the manuscript. All authors have read and approved the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

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