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Seeing and doing: Feasibility study towards valuing visual impairment using simulation spectacles

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Abstract

Elicitation of utilities from those who do not have the health condition of interest generally uses verbal description of health states. This paper reports on the results of a small-scale investigation on the feasibility of an alternative approach, where health states are simulated and thus directly experienced by respondents. Three visual impairment health states were simulated using plastic spectacles, and were evaluated using the time trade-off. The first group of respondents (n = 19) found it difficult to assess visually impaired health states without referring to their own current health. With a further group of respondents (n = 14), we investigated the use of the respondents' current health as the upper anchor of the time trade off. Regression analysis shows that whilst there is a positive effect (p = 0.05) of the respondent's own health state on the values from the first group, there is a non-significant negative effect (p = 0.36) on the values from the latter group with this revised method. Thus, it is feasible to simulate visual impairment in valuation exercises, but care must be taken to ensure what health state is effectively being valued.

Key words

utility assessment, health-related quality of life, public preferences, time trade-off, visual impairment

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1. Introduction

There are many issues associated with valuing health states, such as how those states should be valued and who should be asked to value them.(1;2) Within this latter debate, a recurring theme is that subjects who do not have the condition in question do not know for real what it is like to be in the health state. Advocates for values obtained from representative samples of the general public therefore stress the importance of *informed* public values.(3) This study addresses the issue of how to inform respondents of the health states to be valued. When valuations are elicited from subjects who do not have the condition in question, the usual practice is to give them some form of verbal description of the state to be valued. This can be done by using generic health state classification systems such as the EQ-5D(4), the Health Utility Index Mark 3 (HUI-3)(5), or the SF-6D(6), or by naming a condition, perhaps accompanied by a description of that condition. Either way, the information given to respondents about the health state is highly selective. This means that a health state description may not provide the details that the respondent would have found relevant and important if they had been given complete information.

Different approaches to presentation have also been taken. For example, audiotapes for impaired speech(7) and video clips for other disabilities(8) have been used. These are alternative ways to "present" impaired states; respondents could hear or see a condition but not "experience" it.

The objective of this small-scale study is to explore whether health states associated with progressive eye disease can be presented to non-patient respondents in the form of simulated states, so that the states are "experienced" by them. In order to simulate visual impairment, large plastic spectacles, or goggles, representing different degrees of impaired vision are used. This paper reports on the design and results of a feasibility study.

2. Methods

2.1 The basic structure of the interviews

The structure of the interviews is summarised in Figure 1 (version 1). All respondents were first asked to describe their own health in terms of the EQ5D, two questions on vision taken from the HUI-3, and three questions on visual function from the VFQ25(9). These questions are referred to as "EQ5D+5" and are shown in Figure 2.

Respondents were then asked to try on three pairs of spectacles, representing varying degrees of visually impaired health *states*, and to rank them in order of preference. Those respondents already wearing glasses could put the study spectacles on top. These three health states were then valued in a pre-determined order. The spectacles representing the first state were handed to the respondent, and they were systematically invited to walk around the room, look at books and out of the window for a short time (one minute approximately). This was to help them to assess their ability to accomplish activities with visual impairment and the various implications of the condition on quality of life. All interviews took place at the same location, which was unfamiliar to them. They were then asked to complete the EQ5D+5 questionnaire for that state, with spectacles on, with the help of the interviewer. They could then take the spectacles off for the valuation task, using the time trade-off (TTO) method. The procedure was repeated for the second and third states.

There was a series of further exercises using health profiles, constructed from the three independent health states. All material related to health profiles are reported in Appendix 3. Finally, the respondent was asked a series of background questions, which were taken from the standard EQ-5D questionnaire and modified to ask about the respondent's experience in visual impairment as opposed to severe illness in general.

2.2 The health states and the time horizon variants

Three health states (and two health profiles) representing visual impairment associated with an unspecified progressive eye disease were evaluated in this study. There is degrading vision, and a surgical intervention is available to prevent further visual loss, though damages caused by the disease cannot be reversed. The three states were designed after: mild visual impairment, severe visual impairment, and a post-operative vision. These were labelled A, B, and C respectively, and each respondent valued the states in this order, irrespective of their own ranking of the states. Spectacles A represent unambiguously better vision compared to B or C. However, while spectacles B and C represent two different types of blurred vision, it was not obvious which represented better vision.

When using the TTO method, a common duration across all respondents is sometimes specified. For example, a 10-year fixed duration was used to generate the UK population value set for the EQ-5D(10). However, a 10-year duration is unrealistic for respondents in the younger age groups. On the other hand, a much longer time horizon will be unrealistic for older respondents. Therefore, three respondent age groups were formed and different time horizons were used for each, to reflect roughly the differences in life expectancy across these groups, in line with the original formulation of the TTO method(11). Respondents aged 60 and over were given a 10-year time horizon variant, and those aged 40 to 59 were given a 20-year time horizon variant. Furthermore, due to the study design related to the health profiles, there were two variants with a 40-year time horizon for younger respondents, aged 18 to 39. These two variants were identical with respect to the exercises on health states reported in this paper. Therefore, they are pooled in this paper and in what follows we will refer to the three time horizon variants.

2.3 Deriving values - Introduction of a second questionnaire version with a different TTO upper anchor

The same TTO board and interviewer scripts(12) were used as in the study on Measuring and Valuing Health that estimated the UK EQ-5D population value set, with appropriate adjustments for different time horizons. In version 1 of the questionnaire, TTO values for the three health states (and two profiles) were elicited in the standard way; that is, they were valued against a shorter period of time in full health. Respondents were explicitly asked to ignore any possible comorbidity related to their present health state. The value of each state is given by T/T_0, where T is the number of healthy years equivalent to T_0 years in the valued health state (or profile). For simplicity, a zero temporal discount is used. However, some respondents seemed to be unable to ignore their present health conditions when asked to imagine themselves with the visual impairment alone. So a revised protocol, *version 2*, was designed where the health state in question was now defined as the visual impairment *in addition to present health* (i.e. with existing health conditions). To accommodate this change, the anchor for the TTO was also changed, from full health to present health. Thus, to each of the three time horizon variants described above, there are two versions with different upper anchors: version 1 with full health as the upper anchor, and version 2 with present health as the upper anchor.

In version 2, to "chain" the value of each health state through the value of present health, a TTO valuation of present health against full health was introduced near the beginning of the interview (see Figure 1). Assuming the disutility of multiple disabilities is additive (the "additivity assumption" hereafter), the values associated with visual impairment are then calculated as:

$$U(Q_{FHVI}) = U(Q_{PHVI}) + (1 - U(Q_{PH})) = \frac{T^*.T^{**}}{T_0^2} + \left(1 - \frac{T^*}{T_0}\right), \qquad (E1)$$

where Q represents quality of life, subscripts $_{FHVI}$ and $_{PHVI}$ represent visual impairment anchored to full health and present health respectively, T^* is the number of healthy years equivalent to T_0 years in present health, and T^{**} is the number of years of present health equivalent to T_0 years in present health with visual impairment (see the Appendix 1 for a numerical example).

Empirical evidence suggests that the additivity of multiple impairments assumption might lead to an overestimation of global disutility. For example applications of multi-attribute utility theory to establish a utility function for the HUI system have supported a preference interaction that can be approximated by a multiplicative multi-attribute disutility relationship, with attributes being preference complements (i.e., dysfunction attributes are such that the loss in utility across multiple attributes is smaller than the sum of each loss occurring independently)(13). In the present study, therefore, a sensitivity analysis was performed using the assumption that the disutility of visual impairment with an existing health condition is halfway between the disutility of visual impairment alone and the sum of disutilities (we will refer to this as "partial additivity"; see Appendix 2 for details).

2.4 The analyses

As the respondents to each of the three time horizon variants were not equally distributed across the two upper anchor versions, pooling across the three variants could be a source of confounding bias in the comparison between the two versions. Therefore, in order to determine whether time horizon variants could be pooled, we tested for the association between elicited values and variants. As the sample size is small, the non-parametric Kruskall-Wallis test was used. Similarly the difference between upper anchor versions was tested statistically using the non-parametric Wilcoxon test, as there were two versions. Given the small sample size, a 10% significance level is used throughout.

The effect of respondent's own health on the valuations was explored by comparing the results across the two upper anchor versions. This was done by regressing the TTO responses on categorical variables for the health states valued and the respondents' self-reported health (expressed in terms of the EQ5D single index). We used individual level responses and the random effects model to account for trends in individual responses. The regression was run for the two versions separately and the coefficients were compared. We used SAS version 8.2(14) for all analyses.

2.5 The sample

It was judged that around 40 interviews should be enough to establish whether or not the simulation approach is feasible and explore ways to address any difficulties encountered. Therefore, allowing for possible dropouts, 50 participants were to be recruited. Letters of invitation were sent out to 700 people randomly selected from the electoral register in two wards in Sheffield, UK. The reply slip asked respondents to indicate their sex and age group, and to indicate which interview times they could make. They were offered £15 to attend an interview at the University of Sheffield.

3. Results

In reply to the letters sent, 160 (23%) agreed to take part. Amongst these, women and those aged 18-39 were over-represented relative to the general population. Of these, 50 were invited for interview, making sure that there were equal numbers of men and women in each variant, and that there was an even spread across the time horizon variants[1]. Of the 50 invitees, 38 (76%) turned up. The first 5 interviews were treated as pilots for the purpose of interviewer training and to finalise the interview structure. This paper reports the results from the remaining 33 respondents. All interviews took place in the summer of 2001, and were conducted by one of the authors (SA).

Table 1 shows the distribution of the 33 respondents across the three time horizon versions and the two upper anchor versions. Version 1 with full health as upper anchor had 19 respondents, and version 2 with present health as upper anchor had 14.

Mean age was 46 years (SD=21), ranging from 20 to 86, and 45% were women. Interviews lasted between 27 and 117 minutes, and on average 42 minutes (STD=17). None of the interviews was aborted or produced missing values. When asked for feedback, some patients commented about the TTO exercise, but there was no criticism relating to the simulation approach itself.

Self reported health including vision is described in Table 2. As can be seen, 45% reported problems on at least one EQ5D dimension. The distribution of problems across the five dimensions are roughly comparable to those found in the above UK EQ-5D valuation study.(15) Further, 9% indicated having experienced severe visual impairment themselves and 30% reported experience in their family. Among the 14

[1] Because there were two 40-year time horizon variants, which are pooled for the purpose of this paper (see section 2.2 above), in effect, twice as many participants aged 18-39 were invited as those aged 40-59 and those aged 60+.

respondents who valued their present health in version 2, the mean TTO value was 0.82 (STD=0.27).

Table 3 reports mean TTO values by upper anchor version. Values for version 2 are standardised between full health and “dead”. While there is agreement across versions and variants that state A is better than states B and C, the relationship between the latter two states is not clear. The values are not significantly different between time horizon variants (state A: $p = 0.24$; B: $p = 0.36$; C: $p = 0.20$; Kruskall-Wallis test). However, differences between upper anchor versions were statistically significant for two health states and marginal for the third (A: $p = 0.09$; B: $p = 0.13$; C: $p = 0.03$; Wilcoxon test). Note that mean values for version 1 with full health as upper anchor were consistently lower than the mean values for version 2.

Table 4 reports the results of the regression analysis. The last column indicates that there is no statistically significant difference in the intervals between the health states across the two upper anchor versions, and that a significant difference is attributable to the presence or absence of the effect of the respondent’s present health, and the version itself represented by the intercept. Given the small sample size, some care is required to interpret this result: while the 90% confidence intervals for the intercepts do not overlap (-0.354 to 0.479 for version 1; and 0.502 to 1.434 for version 2), there is some overlap in confidence intervals for present health (0.110 to 1.030 for version 1; and -0.766 to 0.285 for version 2). Similar results were observed when time horizon variants were adjusted for, as the variant effect was not statistically significant. Furthermore, this relationship between the versions is robust regarding the method of standardisation of the chained values in version 2: sensitivity analysis using the partial additivity assumption instead of the full additivity assumption resulted in mean values that were 0.09 lower for each state compared with the base case, but greater than with version 1. The effect of respondent’s present health in the regression analysis remained statistically non-significant (coefficient estimate: 0.016; $p = 0.959$; see Appendix 2 for details).

4. Discussion

The objective of this exploratory study was to examine the feasibility of presenting respondents with health states associated with visual impairment using simulation spectacles. Although the sample size was small, several interesting observations can be made.

Experiencing visual impairment for a short time in order to value such a condition was generally well accepted by respondents. They reported in the EQ5D questionnaire that the condition was associated with some level of discomfort, as well as problems walking around. However the feedback was generally positive, suggesting acceptability, and several qualified this experience as “thought-provoking”. The fact that none of the respondents dropped out from the interview and that there were no missing values are positive indications with respect to the acceptability of this method.

The most important and unexpected finding of this study is that some respondents found it difficult to imagine visual impairment alone when there was a pre-existing disability. (Note that between 40-50% of respondents reported some problem on at least one EQ-5D dimension, which itself is not unusual.) This difficulty is not commonly reported in studies that use written descriptions. It may be that, given verbal descriptions, those respondents who are not in full health are able to picture themselves firstly in the described health state (without their present condition) and secondly in full health (again, without their present condition). Alternatively, they might not have been able to do this; and in this case, either the respondents simply did not recognise that they are not being able to do so, or they were aware of their difficulty but did not report it to the analyst. However, when the health state in question is simulated, as in this study, people found it markedly difficult to imagine themselves in the ways required. This is likely to have happened because the simulated experience makes the health state more vivid and realistic, and so it becomes more difficult to imagine the health state in question without the pre-existing condition. A further consideration is the case where the respondent's condition happens to be some mild visual impairment. In such cases it will be very difficult for the respondent to imagine herself with the simulated visual impairment alone, free of the pre-existing visual impairment.

This finding was picked up after a dozen or so interviews, and led to the development of version 2. The health state to be valued was changed from the visual impairment alone to the visual impairment alongside the existing conditions of the respondent, and the upper anchor of the TTO valuation was changed from full health to the respondent's present health. In order to standardise the obtained values, these values then had to be chained to full health via a TTO valuation of the respondent's present health. Whereas the chaining procedure is used here to deal with the *upper* anchor state, previous studies used chaining when "dead" was not acceptable to respondents as the *bottom* anchor, as they refused to compare minor health conditions against immediate death(16). However, the respondents of this study did not refuse to trade between survival and morbidity.

The regression analysis shows that the responses from this version 2 are not affected by respondents' own health level as those from version 1. The regression coefficient for version 1 on the other hand indicates that a 0.1 increment in respondent health level will lead to a 0.06 increment in the TTO values. This contradicts earlier findings where the opposite relationship was observed where health states were verbally presented(17), but is consistent with the possibility that respondents in this study are not evaluating the simulated visual impairment alone, but are instead evaluating visual impairment alongside their existing health conditions.

One of the two central assumptions concerning the chaining procedure used in this study is that it relies on constant proportional time trade-off of TTO responses (see Appendix 1). Although the Kruskall-Wallis test across variants suggests that this assumption holds, since different time horizons used in this study correlate with respondent age, this result does not offer an appropriate test. However, published studies suggest that, while the requirement is often violated at the individual level, it generally holds at the aggregate level (see for example Sackett and Torrance(18), Pliskin et al.(19), Buckingham et al.(20), Bleichrodt and Johannesson(21), and Unic et al.(22)). The second central assumption is the additivity assumption of multiple impairments. The sensitivity analysis outlined in Appendix 2 demonstrated the robustness of the results of this study regarding this assumption.

So, it seems that we are faced with a choice between the analytical simplicity of anchoring on full health and the cognitive ease of anchoring on present health, where there is no obvious correct choice. However, we think that the second choice (using version 2) is better – it is certainly "kinder" to respondents. Moreover, the potential bias in version 1 goes only in one direction, because responses can be confounded by existing conditions, in which case the valuations will be biased downwards. There is no such expected bias in version 2. In this respect, it is interesting to note that TTO values from version 2 are consistently higher than those from version 1.

Admittedly, this was an exploratory study, and as such it did not aim to have a sufficient sample size to detect pre-defined differences between the two versions (let alone to generate values to be used in future economic evaluation of interventions of visual impairment). Statistical methods were used as a tool to identify hypotheses to consider when eliciting utilities based on a simulation approach rather than to actually test such hypotheses. Although no attempt was made to evaluate the power of the reported tests, it was undoubtedly rather low. In particular, pooling of the three time-horizon variants would have been avoided with a larger sample.

Regarding the simulation approach itself, this is a way to provide more global information about the condition than by verbal descriptions, without risking cognitive overload. Both for the practical objective of eliciting more realistic values for a given condition, and for the methodological objective of exploring the relationship between the evaluated health state and the respondents' own health state, we believe that the use of simulations is a promising line of future research. However, there are caveats to be noted. Firstly, if the obtained values are to be used in the context of an economic evaluation of a specific intervention, then care must be taken to make the simulations as realistic as possible to the actual health states in question. The whole point of the simulation approach is that rather than to present the main features of a condition, the condition as a whole is reproduced and experienced. Secondly, most conditions would be ethically unacceptable to simulate even on consenting subjects. For instance, putting respondents through traumatic experiences is unlikely to be ethically acceptable. Thus, only carefully selected conditions will be amenable to this simulation approach.

In summary, there are three main conclusions from this study. First, this study shows that valuing health states and profiles of visual impairment using simulation spectacles is feasible. This should encourage the development of studies to assess the validity of simulation-based elicitation of utilities compared to standard methods. Second, this study draws attention to the issue of what exactly it is that respondents are valuing when they are subjected to TTO exercises (and possibly other valuation methods) to evaluate themselves in hypothetical health states. They may well be evaluating having the hypothetical health condition *in addition to* their current disabilities. Third, this study has proposed a way to account for this potential problem, in a manner that does not impose extra burden on respondents other than one additional TTO question for their own current health state. To the best of our knowledge, the second and third items are novel. Given the small scale of this study, and the potential importance of the implications, they merit further detailed research.

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Table 1. Distribution of respondents across variants and versions

N (%)	Variant			
	long horizon for 18-39	**middle horizon for 40-59**	**short horizon for 60+**	**Total**
Version 1	9 (27.27)	6 (18.18)	4 (12.12)	19 (57.58)
Version 2	8 (24.24)	1 (3.03)	5 (15.15)	14 (42.42)
Total	17 (51.52)	7 (21.21)	9 (27.27)	33 (100.00)

Version 1: description and valuation of full health with visual impairment, anchored on full health.
Version 2: description and valuation of present health with visual impairment, anchored on present health.

Table 2: EQ5D+5 on respondents' own health and the three health states A, B, and C

Question	Present health	Health state 'A'	Health state 'B'	Health state 'C'
EQ5D – Mobility				
- no problems walking about	79%	55%	0%	3%
- some problems	21%	45%	91%	91%
- bedridden	0%	0%	9%	6%
EQ5D – Self care				
- no problems dressing or washing	97%	70%	12%	6%
- some problems	0%	27%	79%	79%
- unable	3%	3%	9%	15%
EQ5D – Usual activities				
- no problems	88%	21%	0%	0%
- some problems	9%	67%	21%	42%
- unable	3%	12%	79%	58%
EQ5D – Pain / discomfort				
- none	76%	55%	27%	27%
- some	21%	45%	52%	48%
- extreme	3%	0%	21%	24%
EQ5D – Anxiety / depression				
- not anxious or depressed	79%	48%	15%	5%
- moderately	21%	42%	42%	39%
- extremely	3%	9%	42%	45%
EQ5D – Full health	55%	12%	0%	0%
HUI3 – Ability to read				
- able without glasses	52%	18%	0%	0%
- able with glasses	48%	45%	3%	0%
- unable to see well enough with glasses	0%	36%	97%	100%
- unable at all	0%	0%	0%	0%
HUI3 – Ability to recognise a friend				
- able without glasses	64%	21%	0%	0%
- able with glasses	36%	61%	6%	3%
- unable to see well enough with glasses	0%	18%	94%	97%
- unable at all	0%	0%	0%	0%

Table 3. TTO valuations of health states

	Version							
	version 1				version 2			
	Variant			All variants pooled	Variant			All variants pooled
	18-39	40-59	60+		18-39	40-59	60+	
Current health	-	-	-	-	0.88	0.33	0.82	0.82
State A	0.64	0.40	0.62	0.56	0.80	0.75	0.71	0.76
State B	0.36	0.25	0.26	0.30	0.53	0.68	0.42	0.50
State C	0.39	0.16	0.26	0.29	0.55	0.68	0.52	0.55

Table 4. Results of the regression analysis: effect of the respondent's present health on TTO valuations

	Version 1		Version 2		*p*-value $B_1 = B_2$ ‡
	B_1	p	B_2	p	
Present health	0.559	0.0516	-0.291	0.3636	0.0515
State B	-0.254	0.0002	-0.266	0.0007	0.8974
State C	-0.266	0.0000	-0.216	0.0015	0.5503
State A †	0	-	0	-	-
Constant	0.072	0.7748	1.010	0.0011	0.0180

† State A is the default dummy.
‡ The *p*-values of the Wald test: $B_1 = B_2$.

Figure 1: Structure of the two interview versions

	version 1 (n = 19)	version 2 (n = 14)
(1) describing present health in EQ5D+5†		
(2) TTO of present health	×	
(3) ranking of visual states A, B, C		
(4) visual state A		
(a) describing state A in EQ5D+5		
(b) TTO of state A		
(5) visual state B		
(a) describing state B in EQ5D+5		
(b) TTO of state B		
(6) visual state C		
(a) describing state C in EQ5D+5		
(b) TTO of state C		
(7) ranking of states A, B, C, and profiles X, Y		
(8) TTO of profile X		
(9) TTO of profile Y		
(10) WTP for difference Y-X		

† EQ5D+5 consists of EQ5D, 2 questions on vision from HUI-3, and 3 selected questions from VFQ25.

In version 1, TTO of the state/profile alone, with immediate death and full health as anchors.
In version 2, TTO of state/profile plus present existing disabilities, with immediate death and present health as anchors.

This paper reports on the results from (1) to (6).

Figure 2: The "EQ5D+5"

EQ5D

(1) Mobility
noproblems walking about / some problems / bedridden

(2) Self Care
noproblems dressing or washing / some problems / unable

(3) Usual Activities
no problems / some problems / unable

(4) Pain/Discomfort
none/ some / extreme

(5) Anxiety/Depression
not anxious or depressed / moderately / extremely

HUI-3

(6) Which one of the following would best describe your ability, during the past week, to see well enough to read ordinary newsprint?
able without glasses / able with glasses / unable to see well enough with glasses / unable at all

(7) Which of the following would best describe your ability, during the past week, to see well enough to recognize a friend on the other side of the street?
able without glasses / able with glasses / unable to see well enough with glasses / unable at all

VFQ-25

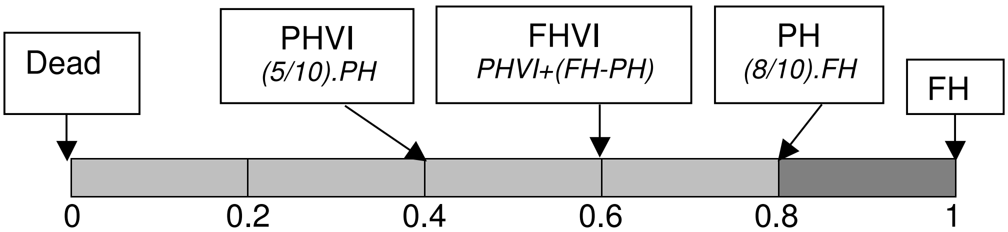
(8) At the present time, would you say your eyesight in both eyes (with glasses or contact lenses, if you wear them) is excellent, good, fair, poor, or very poor, or are you completely blind?

(9) Do you accomplish less than you would like to because of your eyesight?
5levels from "All of the Time" to "None of the Time".

(10) I need a lot of help from others because of my eyesight.
5levels from "Definitely True" to "Definitely False"

Note that these are summaries to illustrate the items included in EQ5D+5 and does not reproduce the exact wording.

Figure 3. An example of utility calculation with the "chained" procedure represented on the utility scale



PHVI: Present Health with Visual Impairment
FHVI: Full Health with Visual Impairment
FH: Full Health
PH: Present Health

Appendix 1: An example of anchoring visual impairment on present health

Suppose a respondent is asked to value visual impairment (VI) with his present health condition (PHVI), using TTO with a time horizon of 10 years. The anchoring state is present health (PH). Suppose further that this respondent is indifferent between 5 years in his present health with no visual impairment and 10 years in his present health with visual impairment.

From this observation, we want to deduct the utility associated with full health with visual impairment (FHVI) on a scale anchored on dead (utility: 0) and full health (FH; utility: 1). In order to do so, the respondent is asked to value his present health against full health. Let us assume that he is indifferent between 8 years in full health and 10 years in present health (see Figure 3).

Since:

5 years in present health = 10 years in present health with visual impairment,

then, using the constant proportional time trade-off assumption:

10 years in present health = 20 years in present health with visual impairment.

Furthermore,

8 years in full health = 10 years in present health.

Then, by transitivity:

8 years in full health = 20 years in present health with visual impairment.

The last statement implies that the utility associated with present health with visual impairment is 0.4. To calculate the utility associated with full health alone (without visual impairment), the value of the difference between present health and full health needs to be added. Given that the utility of full health is 1 and the utility of present health is 0.8, the difference is 0.2. Thus, the utility of full health with visual impairment is 0.6.

Appendix 2: Sensitivity analysis on the additivity assumption of comorbidities

Should one consider that dysfunction attributes are “dispreference” substitutes (i.e., the disutility of multiple impairments is less than the sum of disutilities), a multiplicative multi-attribute utility function would ideally be fitted. However, the protocol was not designed as an application of multi-attribute utility theory(23). Therefore, an alternative approximation was used for the purpose of a sensitivity analysis.

In the example above (appendix 1), we would consider that the disutility of visual impairment with and existing health condition (0.6) is less than the sum of the disutility of visual impairment alone and the disutility of the existing health condition (0.2). This implies that the disutility of visual impairment alone exceeds 0.4, and so it lies in the range [0.4, 0.6]; we assumed that it was the midpoint of this range. Thus the equation *(E1)* was amended as following:

$$U(Q_{FHVI}) = U(Q_{PHVI}) + (1 - U(Q_{PH})) = \frac{T^{*}.T^{**}}{T_0^2} + \frac{1}{2}\left(1 - \frac{T^{*}}{T_0}\right), \qquad (E2)$$

using the same notations as in the text above. We refer to this assumption as “partial additivity”, as opposed to full additivity. Note that this modification does not affect intervals between elicited values.

Appendix 3: Additive separability of health states in profiles

A3.1. Introduction

As is stated in the main text, the study also included a series of exercises on two health *profiles*, composed of the three health *states* A, B, and C, in this order. This Appendix reports on the findings related to these. The objective is to test whether or not the preference for a health profile is equal to the weighted sum of the preferences of the composite health states (weighted by the duration of each state). This is related to the additive separability condition, that the value of a health state should be independent of what precedes or follows it, which is necessary for the aggregation of the value of health states across time to produce the value of a health profile. The alternative hypothesis is that the value of a declining health profile will be less than the weighted average of the composite health states.(24)

A3.2. Methods

The first profile, X, represented the natural progression of the disease from mild to severe visual impairment, followed by the post-operative state (A - B - C). The second profile, Y, represented the pathway with a medical intervention that slowed down the progression of the disease, so that it took longer to move from state A to state B, and thus to state C: i.e. the timing of the operation was delayed. In either profile, no account was made of the *transition* from state B to C: i.e. the pain, trauma and discomfort associated with the laser operation itself.

Taking the 40-59 age group as the reference case, the baseline for profile X was 10-4-6: i.e. 10 years in the mild state, 4 years in the severe state, and 6 years in the post-operative state. Profile X for the 60+ age group was proportional to this: i.e. 5-2-3. Under the assumptions of additive separability and constant proportional time trade-off, the same values would be expected for proportional health profiles 10-4-6 and 5-2-3, after adjustment for time-preference. The 18-39 age group was broken up into two subgroups. The first subgroup was given a profile that was proportional to the reference case, i.e. 20-8-12. However, should respondents have a positive rate of time-preference, elicited values would be little sensitive to the time spent in the last states. Therefore, the second subgroup was given a profile comprising of 10-4-26, which means the first 20 years of their time horizon is split in the same way (10-4-6) as in the reference case. Respondents aged between 18 and 39 were allocated randomly to one of these two subgroups.

The baseline for profile Y was generated by extending the duration of the mild state by 4 years and leaving the duration of the severe state unchanged, thus delaying the post surgery state by 4 years. Therefore, Profile Y for the 40-59 age group was 14-4-2. Retaining proportionality, Profile Y for the 60+ group becomes 7 years in the moderate state, followed by 3 years in the severe state, with no post-operative state (7-3). Profile Y for the two 18-39 subgroups was constructed following the rules above, resulting in health profiles of 28-8-4 and 14-4-22. Thus, there are now four time horizon *variants*: "10-year time horizon variant", "20-year time horizon variant", "40-year time horizon F", and "40-year time horizon P" (where "F" and "P" for the 40-

year time horizon variants stand for fixed and proportional health profiles). The durations and health profiles are summarised in Figure A3.

After the TTO of the individual health states, the two health profiles were presented to the respondents and they were asked to rank them alongside the three states. They then valued each of the two health profiles to provide *direct* TTO valuations. The profiles were presented in the form of a diagram showing the different durations of the three states (Figure A3).

Since health profiles X and Y are combinations of states A, B, and C, and since all the states and profiles evaluated by a given respondent last for the same total duration, there is a logical ordering to the health states and profiles, enabling to test for internal inconsistencies. A respondent was defined as "inconsistent" if his (direct) TTO valuations did not reflect either of the following orderings: A f Y f X f B f C, or A f Y f X f C f B. The difference between the severe and post-operative states is not obvious and so C f B was not treated as an inconsistency.

Further, *indirect* TTO values for profiles X and Y were calculated for each individual, using the TTO values of composite states A, B, and C. A zero time preference rate is used in the initial stage. Should the direct and indirect values differ, a time preference rate that will make them coincide at the aggregate level will be calculated.

A3.3. Results

At the individual level, a small number of respondents (three from version 1 and one from version 2) violated the relationship that profile X is better than the worst state (the smaller of B and C). However, the consistency rates were very good overall.

Table A3.1 reports the aggregated direct and indirect TTO values for profiles X and Y, including those with inconsistent results. the indirect values for profile Y are higher than for profile X. It can be seen that the difference across versions is greater than the difference between profiles within a version. Comparison with Table 3 indicates that, at zero temporal discount, the direct values of the declining profile are lower than the corresponding indirect values, thus violating additive separability. The temporal discount rates at which the direct and indirect values of these profiles coincide are negative (-10% for X and -12% for Y).

Table A3.2 illustrates the results of the regression analysis, by including the direct TTO values of the two profiles. As can be seen, the observations made in the main text continue to apply.

A3.4 Discussion

Few respondents had ordinal inconsistencies in the TTO responses and the differences in TTO values between the different health states and profiles were robust across two versions of the protocol. Arguably, defining certain rank ordering of TTO values as "inconsistent" when the states have no logical ordering may be problematic. However, all the cases of inconsistency in the rank ordering of TTO values occurred where this ordering did not follow the direct rank ordering of the health states and profiles by the same respondent. Thus, these so-called "inconsistencies" might reflect measurement error associated with the TTO method rather than unexpected preferences.

The results regarding the direct and indirect values for the two health profiles suggest the violation of additive separability at the aggregate level, under the zero discount rate assumption. The present results are consistent with the theoretical concern over this assumption that predicts direct values of declining profiles will be lower than their indirect values. If we relax the zero discount assumption, then the present results are consistent with additive separability if discounting is negative. Negative time preference has been observed in other studies.(25) However, a negative time preference rate would imply that preference weights for life-years would increase exponentially with time. Hence values elicited with a 40-year time horizon would likely exceed values elicited with 20- or 10-year time horizons. For example, if an individual values a state at 0.5 and has a time preference rate of -10%, the expected elicited values non-adjusted for temporal discounting would be approximately 0.60 with a 10-year time horizon, 0.71 with 20-year and 0.82 with 40-year time horizon. This type of trend is not apparent in the comparison between variants. However, it is unclear whether the data are consistent with negative discounting as differences between variants are not significant, and valuations may also depend on age (1). Perhaps a possible explanation is that respondents considered that the fear of future degradation of vision would affect their quality of life and would make more difficult the adaptation to visual impairment.

Additional references

(24) Richardson J, Hall J, Salkeld G. The measurement of utility in multiphase health states. Int J Technol Assess Health Care 1996; 12(1):151-162.

(25) Loewenstein G, Prelec D. Negative Time Preference. The American Economic Review 1991; 81(2, Papers and Proceedings of the Hundred and Third Annual Meeting of the American Economic Association):347-352.

Table A3.1. Direct and indirect TTO values for profiles X and Y

	version 1		version 2	
	direct	indirect	direct	indirect
Profile Y (with intervention)	0.41	0.45	0.61	0.68
Profile X (without intervention)	0.34	0.41	0.57	0.64
n	19		14	

Table A3.2. The effect of the respondent's present health on TTO valuations

	Version 1		Version 2		*p*-value $B_1 = B_2$ ‡
	B_1	p	B_2	p	
Present health	0.570	0.044	-0.241	0.443	0.058
State B	-0.254	0.000	-0.266	0.001	0.897
State C	-0.266	0.000	-0.216	0.001	0.550
Profile X (direct)	-0.214	0.000	-0.194	0.003	0.792
Profile Y (direct)	-0.149	0.001	-0.153	0.003	0.948
State A †	0	-	0	-	-
Constant	0.063	0.800	0.968	0.001	0.020

† State A is the default dummy.
‡ The *p*-values of the Wald test: $B_1 = B_2$.

Figure A3: The two profiles and the four variants

Fig A3.a Profiles for the 18-39 age group, variant '18P'

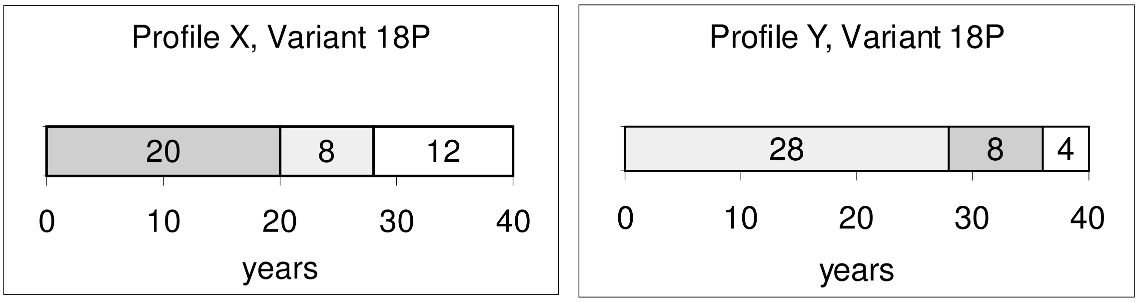


Fig A3.b Profiles for the 18-39 age group, variant '18F'

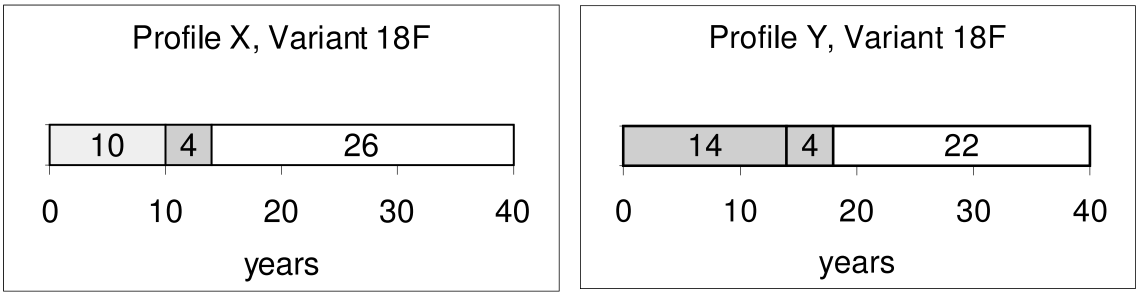


Fig A3.c Profiles for the 40-59 age group

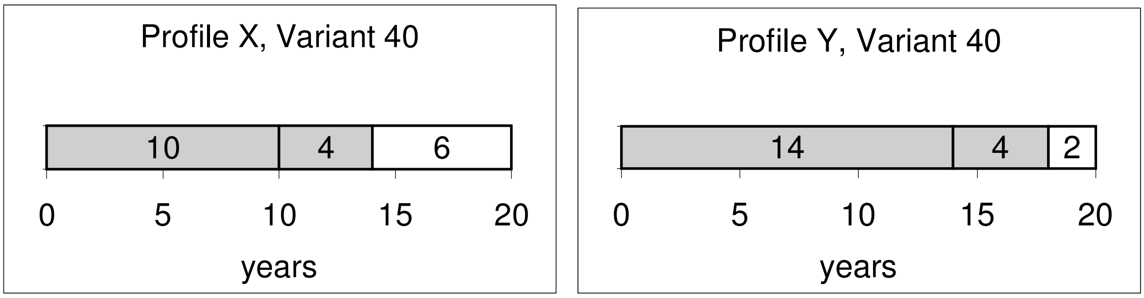
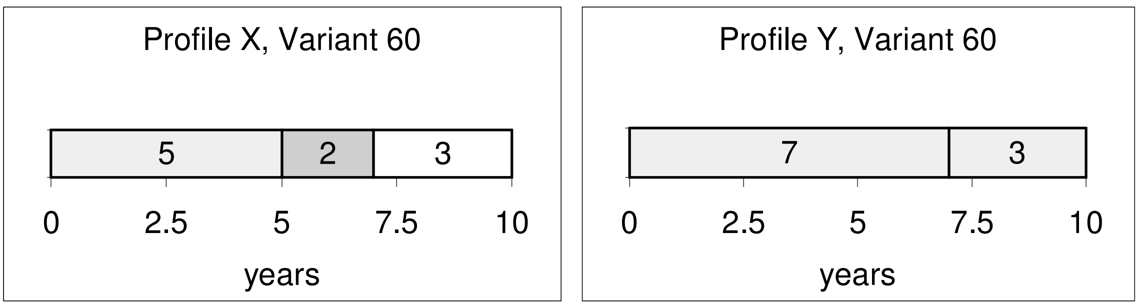


Fig A3.d Profiles for the 60 and above age group



Legend