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The Self Time Trade-off (TTO) Instrument: Reliability and Survey Results

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ABSTRACT

The Self TTO is a variant of the time trade-off (TTO) instrument used for estimating health state utilities. The distinctive feature of the Self TTO is that the health state evaluated is the respondent's own health state rather than a hypothetical state. The rationale for the instrument is that, according to welfare theory, it is the individual's preference for their own health state which should be included in the calculation of quality adjusted life years (QALYs). While conventional measurement asks individuals to imagine that they are in the health state to be evaluated, their capacity to change their perspective and evaluate the hypothetical but unexperienced health state is unknown. The framing and perspective of questions, however, are known to have powerful effects upon respondents' answers and the perspective and framing of the Self TTO are the closest to the theoretical ideal. The Self TTO is therefore an alternative and theoretically supported method for measuring utility, but also a method for testing the validity of other measures of utility.

This paper has four parts. In the first, a web-based algorithm for the measurement of the Self TTO is described. In the second, results of its use in a Multi Instrument Comparison (MIC) survey are reported and compared with utilities estimated from five MAU instruments in the MIC survey. In the third part, the 'content' of the self TTO is examined by comparing it with the independently measured dimensions of the SF-36 and AQoL-8D. Finally, results from test-retest analyses of the instrument's reliability are reported.

Results indicate that a majority of survey respondents were unwilling to trade a large part of their life in exchange for improved quality. The average self TTO is significantly higher than the average utility obtained from other instruments. At the individual level self TTO results are unreliable, but pooled data correlate highly with results from other instruments. Variation in the self TTO is chiefly associated with psycho-social dimensions of health. Incremental change in the self TTO is similar to incremental change in the SF-6D.

It is concluded that while the Self TTO is too insensitive to be a stand-alone metric it potentially fulfils its initial purpose which was to test the validity of other metrics. Additional investigation is needed to validate the online algorithm and to determine optimal edit procedures.

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The Self Time Trade-off (TTO) Instrument: Reliability and Survey Results

1 Introduction

Cost Utility Analysis (CUA) estimates the cost of obtaining an additional quality adjusted life year (QALY) where QALYs are calculated as the product of life years and utility (QALY = LY*U). According to orthodox welfare theory the utility used in this calculation should be the strength of preference of the person affected by the health state and to quantify this individuals are commonly asked to imagine that they are in the health state to be evaluated. Each of the major MAU instruments used for measuring utility adopts this approach. However the health state described and evaluated by people are not their own and people's ability to imagine themselves in a hypothetical state is unknown. The perspective achieved in such measurement is therefore more correctly described as 'quasi-personal': midway between the personal and the impersonal.

Changing perspective may significantly alter the assessment of a health state. This is illustrated by the effect of shifting from a quasi-personal to a fully impersonal or 'social' perspective which is embodied in the relative social willingness to pay. The 'arm's length' perspective in this instrument results in highly correlated but significantly lower values for health states (Richardson et al. 2013). This suggests that a shift from a quasi to a fully personal perspective may similarly have an impact upon measurement.

Even if such an effect was superficially small the difference in measured utility may have significant effects on apparent cost effectiveness. For example, if the health state utility associated with a disease was 0.85 according to one metric but 0.9 according to another, then a cure of the disease which raises utility to 1.00 adds 0.15 and 0.1 to utility as measured by the two metrics; that is, there is a 50 percent difference. The effect upon the estimated number of (undiscounted) QALYs in this example would be equivalent to a 50 percent increase in life expectancy.

In view of its importance, the validation of the units in which utility is measured has received relatively little attention in the literature. This is probably attributable, in part, to the initial view that the validity of the units was ensured if they were derived from the standard gamble or if, like the TTO, they produced results similar to the standard gamble. However the numbers produced by the standard gamble are problematical for both psychometric and theoretical problems associated, respectively, with the difficulty individuals encounter with the treatment of probabilities, and with the existence of a (dis) utility of gambling per se which, as Von Neumann and Morgenstern noted, is not taken into account in the axiomatisation of the standard gamble

(Morgenstern 1974). In the absence of a gold standard it is questionable whether or not extant methods for measuring utility, or the MAU instruments whose formula are based upon these methods achieve what Richardson (1994) described as a 'strong interval' property. This is the requirement that a given percentage change in 'utility' as measured by an instrument will be equally valued as the same percentage change in life expectancy by the person affected. While it is difficult to test this property it is fundamental to the validity of the QALY as a unit which combines the length and quality of life. Possibly reflecting this difficulty the literature has largely ignored the problem.

The present paper describes a new method for testing the units of utility, namely the use of a Self TTO instrument. This is a version of the time trade-off (TTO) technique for evaluating a health state utility. By contrast with the conventional TTO it shifts the frame of reference to the most personal and (for orthodox theory) the theoretically correct level. The conventional TTO offers people a trade-off between time in a hypothetical (poor) health state and reduced time in excellent health. The Self TTO replaces the hypothetical health state with a person's current health state. The Self TTO therefore measures only one health state, namely the health state of the respondent. Its potential use is twofold. First, it is an independent test of the utility values produced by other instruments for the individual's health state. Secondly, it could, in principle, be used to recalibrate the descriptive systems of MAU instruments.

The present paper has four objectives. First, in Section 2, a web based algorithm for estimating the Self TTO is described. Secondly, in Section 3 data are presented from the use of the algorithm with 8,022 individuals included in a Multi Instrument Comparison (MIC) survey. Mean scores are compared by disease group with the utilities obtained from five MAU instruments (MAUI) included in the survey. Variation in each of the MAUI utilities is compared with variation in self TTO. The focus in this section of the paper is upon the strong interval property and whether the magnitude of incremental utilities predicted by the MAU instruments corresponds with the magnitude of the change in average self TTO. The third objective – Section 4 – is to report results of an analysis of the content of the self TTO: the dimensions of the QoL which are associated with changes in respondents' willingness to trade life for QoL. The fourth objective, outlined in Section 5, is to present results of a test-retest analysis of the reliability of the self TTO. It is concluded that while the Self TTO is too insensitive to be a stand-alone metric it potentially fulfils its initial purpose which was to test the validity of other metrics. Additional investigation is needed to validate the online algorithm and to determine optimal edit procedures.

2 Online Self TTO

The conventional time trade-off (TTO) technique for measuring health state utilities was introduced into health economics by Torrance who provides a description of the method (Torrance 1986). The technique is based upon a person's willingness to trade-off years of life in a health state for a reduced number of years in excellent health. For example, if a person is willing to sacrifice a maximum of 4 years and live for 6 years in excellent health rather than live for 10 years in a poor health state then the utility index for the poor health state (ignoring time discounting) would equal 6/10 = 0.6.

The TTO generally employs a 'flip-flop' technique. This initially changes time in the excellent health state by large increments and subsequently narrows the range of options as the interview progresses. For example, the time in excellent health in successive iterations may be 10, 1, 9, 2, 8.5, 3. 8.0, 5, 7, 7.5, 6, 7.5, 7, 7.25 years at which stage equivalence may be reached. In principle, the advantage of the technique is twofold. Firstly, it increases deliberation by respondents. Secondly, it prevents bias from the 'anchoring effect' identified by Kahneman and Tversky (1974). This refers to the tendency for people who are unsure of a quantity to be influenced by a number which is suggested to them. Flip flopping changes the anchor and seeks to overcome this bias.

In principle, the online Self TTO follows the methods used in a conventional TTO interview. To mimic these conditions, information and questions are presented in an animation by an avatar. After a brief introduction relating to the purpose of the exercise, the concept of 'best possible health' is described in detail (see Box 1). Throughout the interview respondents are reminded that 'best possible health' means the 'best possible physical, social, mental and emotional health'. After the initial description, individuals are asked whether their present health is poorer than best possible health. Those answering that it is equal to best health and confirming this answer when it is queried are assigned a utility score of 1.00.

Those responding that their health is less than the best possible proceed with a trade-off exercise. This commences by asking the respondent to imagine that they will live for only 10 years in their present health state but that the health state will not change over this time. They are then asked if they would be willing to live a shorter period ('for example, 9 years and 11 months') in the best possible health state. The 'flip-flop' procedure then commences as shown in Box 2. At each iteration of the exercise the options are presented in animation form as shown in the screenshot in Box 3. Questioning continues until the maximum willingness to trade is obtained. As a final confirmation that the answer is correct the avatar asks whether the number really represents the 'most time' that the respondent is willing to give up. As with the conventional TTO, a utility score (undiscounted for time) is calculated from the ratio of time in excellent health to time in own health, ie as final years derived from the trade-off divided by ten.

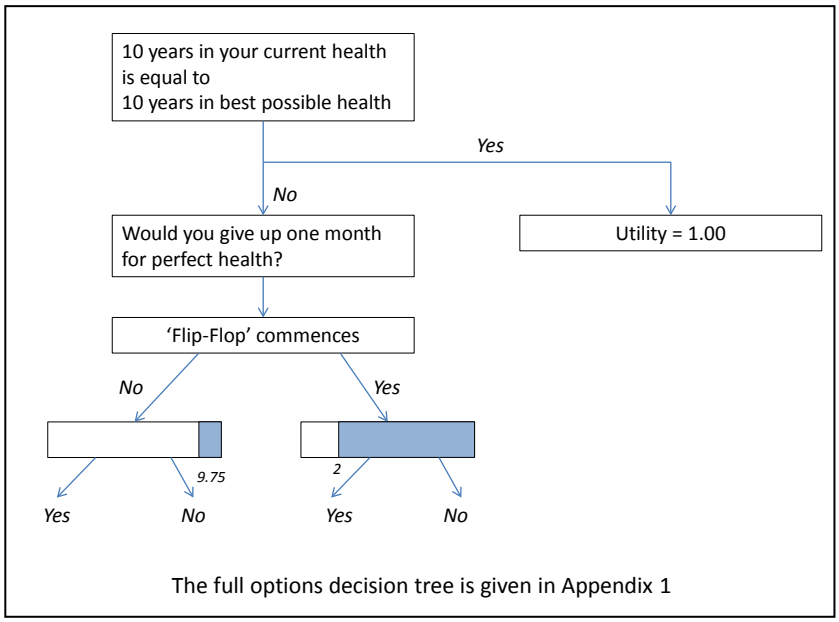
The text used by the avatar is reproduced in Appendix 1 and the full options in the decision tree are shown in Appendix 2.

Technical details about the technique may be assessed from 'Online TTO' on the AQoL website (www.aqol.com.au or Google 'AQoL').

Box 1 'Best possible health' text spoken by avatar

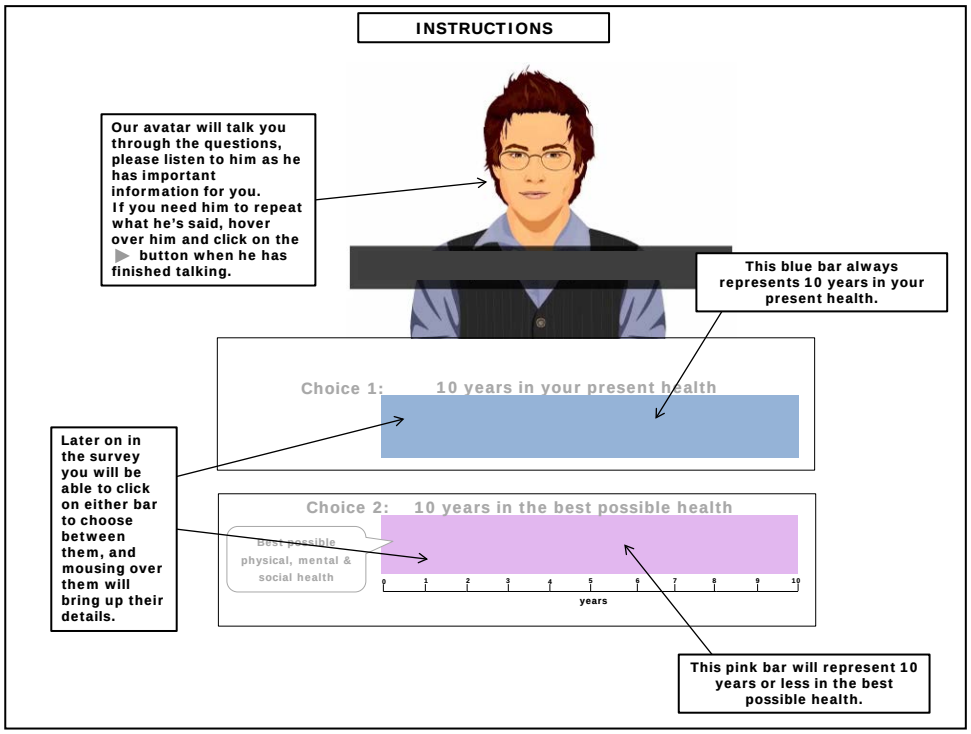
The best health possible means you have an extraordinary sense of wellbeing with NO symptoms or impediments at all. Your physical health is excellent - you have no pain or discomfort. Your hearing, vision and speech are perfect. Your energy, strength and flexibility are at their peak. Mentally you are happy, enthusiastic, and confident and you have a high self-esteem. You're never sad, depressed, worried or anxious. And to top it off, you have excellent social and family relationships. It simply can't get any better than this.

Box 2 Commencement of the algorithm



The full options decision tree is given in Appendix 1

Box 3 Visual representation of a trade-off



3 Self TTO and Multi Attribute Utility

The Multi instrument comparison (MIC) study is described in Richardson (2012a). Country specific reports are available online from the AQoL website (Richardson et al. 2012a-f). The project administered twelve health related quality of life instruments and the Self TTO to 9,665 individuals in six countries. After editing 8,022 records were retained which included individuals in seven disease areas and from the general public. Instruments included are reported in Table 1 which cites the study from which utility weights were derived. Sample characteristics are described in Table 2.

Table 1 Instruments included in the MIC survey

Countries: Australia, USA, UK, Norway, Germany, Canada	
Disease Areas: Asthma, Arthritis, Cancer, Depression, Diabetes, Hearing loss, Heart disease. Healthy (no disease)	
Instruments	
Subjective wellbeing (happiness)	PWI, IHS, SWLS
Multi attribute utility (MAU)*	EQ-5D-5L[(1)], SF-6D[(2)], HUI 3[(3)], 15D[(4)], QWB[(5)], AQoL-4D, AQoL-8D[(6)]
Multi attribute (MA) (non utility)	SF-36
Capabilities	ICECAP-A
Self-assessment	VAS, Self TTO, Categorical
Disease specific	1 per disease area
Other	Demographics, SES

Notes:

*Utility formula for the instruments were obtained from the following sources: (1) McDonough et al. (2005); (2) Brazier et al. (2002); (3) Feeny (2002); (4) Sintonen and Pekurinen (1993); (5) Kaplan et al. (1976); (6) Richardson et al. (2014).

Table 2 Characteristics of the MIC sample n=8,022

	Male percent				Female percent				Total Male	Total Female	Total
Country	School[(1)]	Dip[(1)]	Uni[(1)]	%+65	School[(1)]	Dip[(1)]	Uni[(1)]	%+65			
Australia	33.0	39.4	27.6	18.5	38.6	30.8	30.6	17.2	710	720	1430
USA	33.4	25.5	41.1	14.6	37.8	31.7	30.6	21.6	560	900	1460
UK	37.6	31.0	31.3	17.8	38.7	29.3	32.1	16.1	686	670	1356
Canada	27.8	45.6	26.6	13.0	30.0	48.8	21.2	19.8	504	826	1330
Norway	24.5	51.4	24.1	18.5	33.2	44.1	22.7	11.2	710	467	1177
Germany	17.7	51.8	30.5	17.6	21.8	58.7	19.5	14.1	678	591	1269
Total[(1)]	28.9	41.1	30.0	100	33.8	39.7	26.5	100	3848	4174	8022
Public	34.0	39.6	26.4		33.3	38.1	28.6		841	919	-

[(1)] School = High school only; Dip = Diploma or certificate of trade; Uni = university qualification

Table 3 Self TTO summary statistics by country

MIC country	n	Mean	Standard deviation	Standard error	Median	Range	IQ range
Australia	1430	0.75	0.34	0.009	0.92	1.00	0.34
USA	1460	0.80	0.30	0.007	0.97	1.00	0.24
UK	1356	0.78	0.30	0.008	0.92	1.00	0.29
Canada	1330	0.80	0.30	0.008	0.97	1.00	0.24
Norway	1177	0.82	0.30	0.008	0.97	1.00	0.11
Germany	1268	0.75	0.35	0.010	0.97	1.00	0.29
Total	8021	0.78	0.32	0.003	0.97	1.00	

Table 4 Self TTO summary statistics by health state

Respondent group	n	Mean	Standard deviation	Standard error	Median	Range	IQ range
Public	1760	0.89	0.23	0.005	0.99	1.00	0.09
Asthma	856	0.80	0.29	0.010	0.97	1.00	0.24
Cancer	772	0.76	0.32	0.011	0.92	1.00	0.29
Depression	917	0.62	0.38	0.012	0.75	1.00	0.83
Diabetes	923	0.77	0.32	0.010	0.92	1.00	0.29
Hearing problems	932	0.82	0.30	0.010	0.97	1.00	0.13
Arthritis	929	0.76	0.32	0.010	0.92	1.00	0.29
Heart disease	943	0.77	0.32	0.010	0.92	1.00	0.29
Total	8021	0.78	0.32	0.003	0.97	1.00	

Table 5 Pearson Correlations between instruments

MAU instruments				Non MAU instruments	
EQ-5D	0.35	15D	0.38	ICECAP(1)	0.36
SF-6D	0.38	QWB	0.33	PWI(2)	0.30
HUI 3	0.36	AQoL-8D	0.42	SF-36(3)	0.39

(1) 'Capabilities' (Coast et al)

(2) Personal Wellbeing Index (subjective wellbeing): Cummins

(3) Addition of mental and physical component scores

Table 6 Mean values, Self TTO, MAU scores by disease group

Disease	Stats	Self TTO	EQ-5D	SF-6D	HUI3	15D	QWB	AQoL-8D
Public	Mean	0.89	0.88	0.8	0.88	0.94	0.74	0.83
	SE	0.006	0.003	0.003	0.003	0.002	0.004	0.003
Asthma	Mean	0.81	0.76	0.71	0.76	0.85	0.63	0.69
	SE	0.01	0.007	0.004	0.008	0.004	0.006	0.007
Cancer	Mean	0.77	0.7	0.69	0.68	0.82	0.6	0.66
	SE	0.012	0.008	0.005	0.01	0.005	0.006	0.008
Depression	Mean	0.62	0.59	0.6	0.53	0.76	0.54	0.45
	SE	0.013	0.008	0.004	0.01	0.004	0.005	0.006
Diabetes	Mean	0.77	0.71	0.7	0.68	0.84	0.61	0.66
	SE	0.011	0.008	0.005	0.009	0.004	0.006	0.007
Hearing problems	Mean	0.82	0.79	0.75	0.7	0.88	0.64	0.72
	SE	0.01	0.006	0.004	0.008	0.004	0.005	0.007
Arthritis	Mean	0.77	0.64	0.67	0.62	0.82	0.58	0.63
	SE	0.011	0.007	0.004	0.008	0.004	0.005	0.007
Heart disease	Mean	0.77	0.72	0.7	0.7	0.83	0.61	0.68
	SE	0.011	0.007	0.004	0.008	0.004	0.006	0.007
Total	Mean	0.79	0.74	0.71	0.71	0.85	0.63	0.68
	SE	0.004	0.003	0.002	0.003	0.001	0.002	0.003
MAE: Self-TTO - MAUI			0.05	0.08	0.08	-0.06	0.16	0.11

Summary Statistics: Mean and median values for the Self TTO by country and by disease categories are shown in Tables 3 and 4. The large differences between mean and median values of the self TTO and the large standard error of the mean reflect the highly skewed distribution of scores. Nine percent of respondents would not trade and over 50 percent would trade only 3 percent or less of their remaining life in exchange for excellent health. Mean values are therefore largely determined by the minority of respondents who were prepared to trade significant years of life. When this occurred, respondents favoured 'rounded numbers' of years (9.0, 8.5, 7.5 etc). The frequency distribution is reported in Appendix 3.

Pearson correlation between Self TTO and the other HRQoL instruments included in the MIC survey are reported in Table 5. Correlations are relatively low reflecting the highly skewed and discontinuous frequency of the Self TTO. The correlation with utility varies significantly with the MAU instrument from 0.42 for AQoL-8D to 0.33 for QWB. Coefficients are greater than for the correlation with subjective wellbeing as measured by the PWI or SWLS but not significantly different from the correlation with the unweighted measure of HRQoL, the SF-36.

Results by Disease Group: Mean scores for the self TTO are contrasted with the mean utilities obtained from the major MAU instruments for each disease category in Table 6. Table 7 reports the loss of utility, as compared with the healthy public. These results are used to estimate the difference between the loss of utility measured by the MAU instruments and the self TTO in Table 8. The effect of the disease upon the ranking of utilities is very similar. From Tables 6 and 7 the greatest effect in every case is associated with depression followed by arthritis and cancer. The smallest diminution in utility is associated with hearing loss followed by asthma (except for HUI 3 where this final ordering is reversed).

From Table 8, the EQ-5D, HUI 3 and AQoL-8D over-predict the reduction in self TTO. The average loss of utility predicted by SF-6D, 15D and QWB across all disease groups is very similar to the loss predicted by the self TTO. However results are not uniform. Relative to the self TTO depression is under-predicted by 0.07, 0.09 and 0.07 by the SF-6D, 15D and QWB respectively. Discrepancies in the prediction of self TTO by the other instruments also varies. EQ-5D over-predicts the loss associated with arthritis by 0.12; HUI 3 over-predicts loss associated with hearing by 0.11 and AQoL-8D over-predicts loss associated with depression by 0.11.

Self TTO and MA Utilities: For each MAU instrument respondents were ranked by the utility predicted by the instrument and combined in percentile groups (U = 1.00; 0.99 - < 1.00; 0.98 - < 0.99 etc). Observations with less than 10 individual cases were not included in the analyses. Average Self TTO scores were calculated and regressed upon the average MAU score. Results using the full database are shown in Figures 1(a) to 1(f).

The figures differ significantly. The range of SF-6D and 15D utilities is less than for the HUI 3 and EQ-5D. Consequently, there are fewer observations and more individual cases averaged per observation. This increases the R^2 as the effect of random error is reduced by the increased aggregation.

Table 7 Reduction in Self TTO and loss of utility associated with patient groups

Respondent group	Self TTO	EQ-5D	SF-6D	HUI 3	15D	QWB	AQoL-8D
Public							
Arthritis	0.12	0.24	0.13	0.26	0.12	0.16	0.20
Asthma	0.08	0.12	0.09	0.12	0.09	0.11	0.14
Cancer	0.12	0.18	0.11	0.20	0.12	0.14	0.17
Depression	0.27	0.29	0.20	0.35	0.18	0.20	0.38
Diabetes	0.12	0.17	0.10	0.20	0.10	0.13	0.17
Hearing problems	0.07	0.09	0.05	0.18	0.06	0.10	0.11
CHD	0.12	0.16	0.10	0.18	0.11	0.13	0.15
Mean	0.13	0.18	0.11	0.21	0.11	0.10	0.19

Table 8 Reduction in MA Utility (Pub-Patient) minus reduction in Self TTO (Pub-Patient)

Respondent group	EQ-5D	SF-6D	HUI 3	15D	QWB	AQoL-8D
Arthritis	0.12	0.01	0.14	0.00	0.04	0.08
Asthma	0.04	0.01	0.04	0.01	0.03	0.06
Cancer	0.06	-0.01	0.08	0.06	0.02	0.05
Depression	0.02	-0.07	0.08	-0.09	-0.07	0.11
Diabetes	0.05	-0.02	0.08	-0.02	0.01	0.05
Hearing problems	0.02	-0.02	0.11	-0.01	0.03	0.04
CHD	0.04	-0.02	0.06	-0.01	0.01	0.03
Average	0.05	-0.01	0.08	-0.01	0.01	0.06

Figure 1(a-f) Average Self TTO on MA utilities by MA percentile

Figure 1(a)

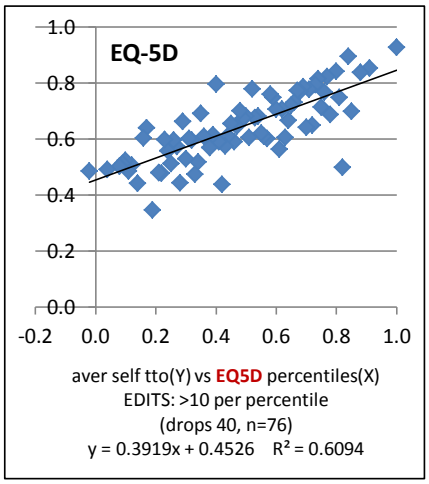


Figure 1(b)

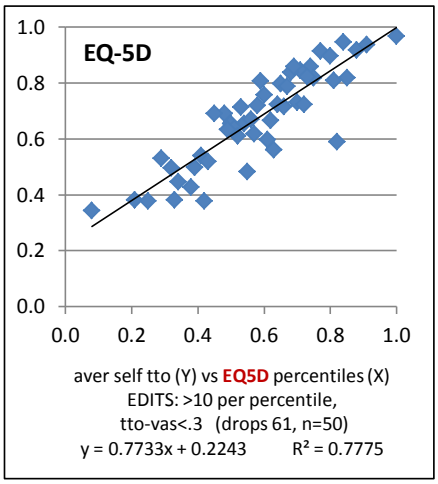


Figure 1(c)

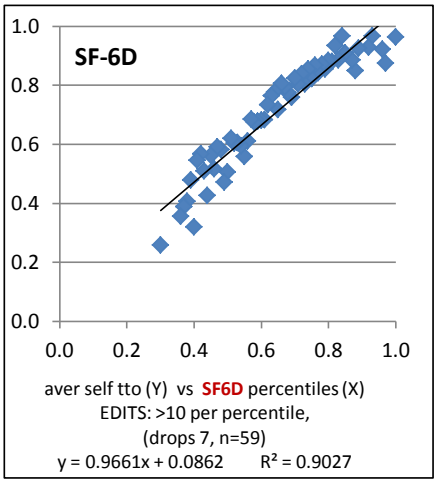


Figure 1(d)

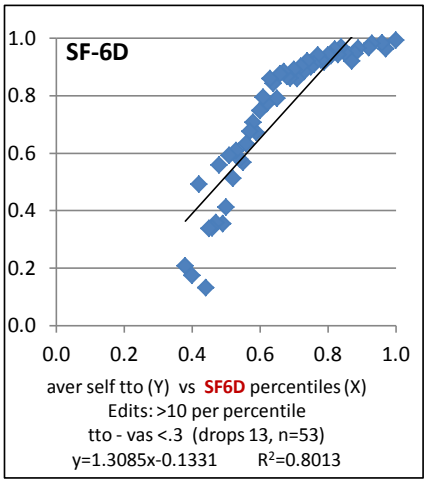


Figure 1(e)

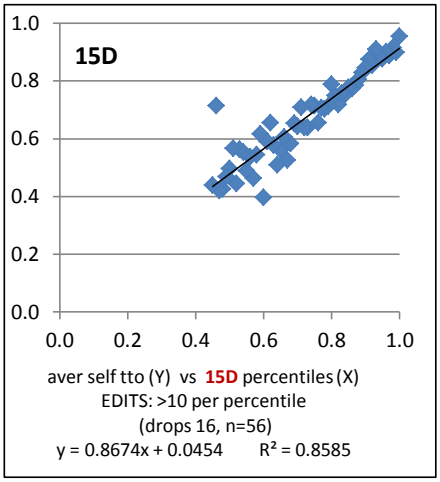


Figure 1(f)

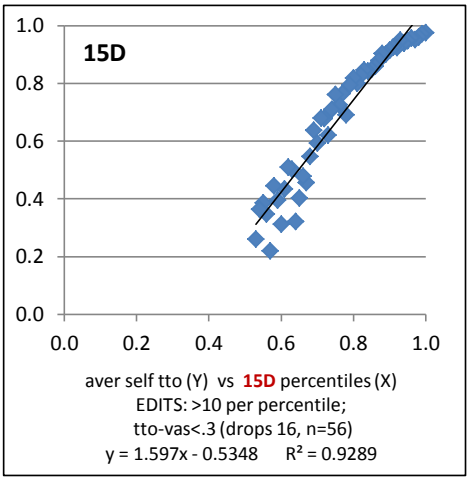


Figure 1(g-l) Average Self TTO on MA utilities by MA percentile

Figure 1(g)

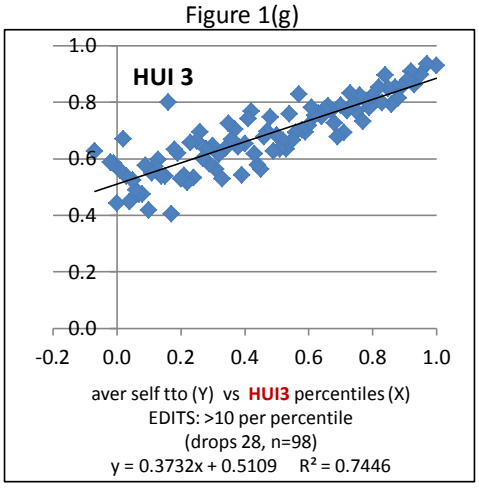


Figure 1(h)

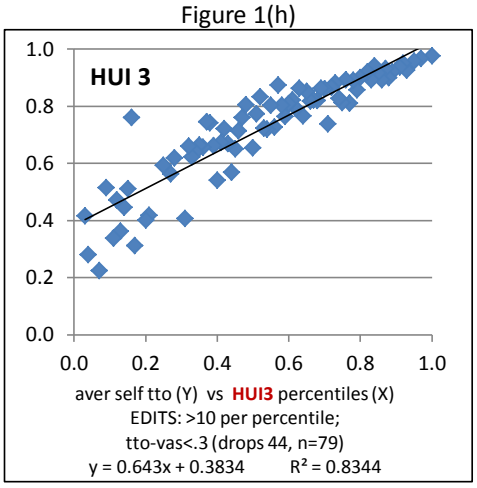


Figure 1(i)

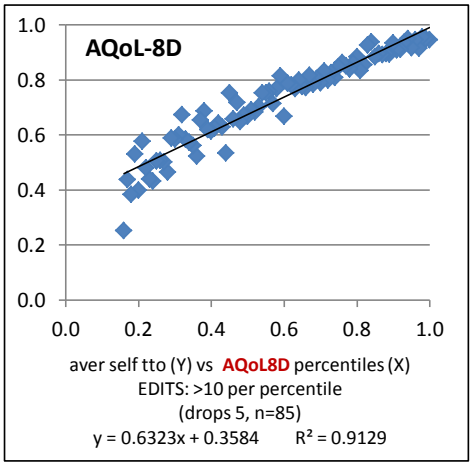


Figure 1(j)

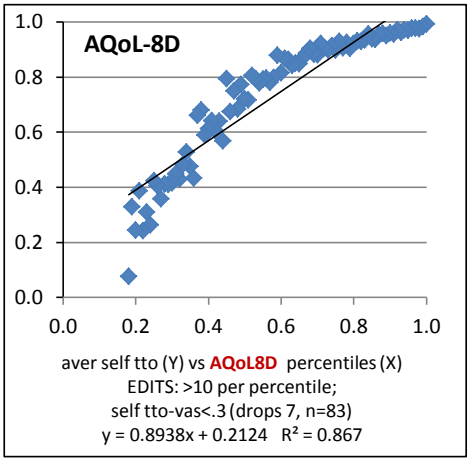


Figure 1(k)

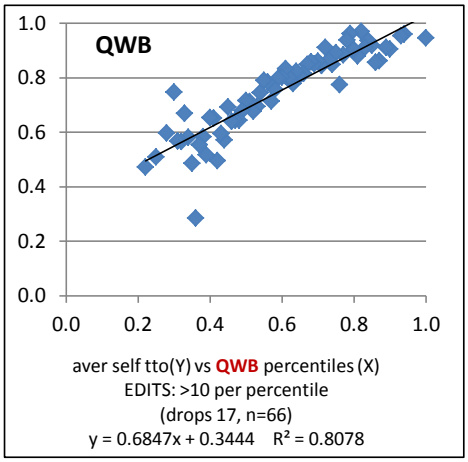
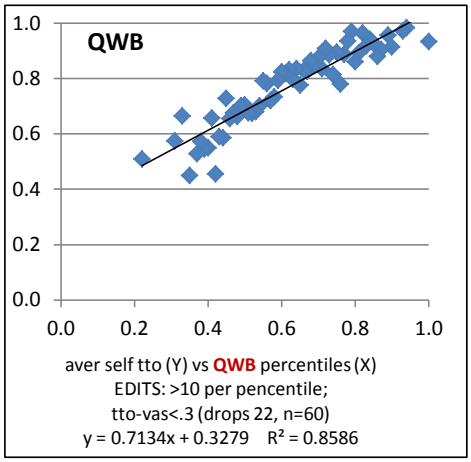


Figure 1(l)



The chief interest in the comparison is not, therefore, the explanatory power of variables but the incremental relationship between them and, more specifically, the extent to which this is consistent with the existence of a strong interval property in the units of utility. This is implied if the absolute value of the incremental utility is equal to the absolute value of the incremental self TTO; that is, in the relationship Self TTO = a + b MAU_i, the parameters b = 1.00. Using this criterion utilities predicted by the SF-6D are close to having a strong interval property, followed by the utilities of the 15D, AQoL-8D, EQ-5D and HUI 3. The results are consistent with the previous analysis in which diminution in utilities and self TTO were compared by disease group.

Test-retest results reported in Section 5 below indicate that individual self TTO results have low reliability. Consequently, an additional edit procedure was applied and cases removed when the self TTO and VAS obtained from the MIC survey differed by more than 0.3. This eliminated 3462 cases or 43 percent of the total. As the average VAS is relatively low and the distribution closer to normal than the highly skewed self TTO this primarily eliminated individuals with low VAS but high self TTO scores. Surviving cases with low VAS therefore had, on average, a low self TTO which reduced average self TTO values disproportionately for those with low scores. The slope of the regressions therefore increased as shown in Figures 1(a) – 1(l). With the edited data the slope coefficient of the AQoL-8D is closest to unity. Coefficients on the SF-6D and 15D significantly exceed unity implying an under-prediction of the change in incremental self TTO by the two instruments.

4 Content

The 'content' of the self TTO is defined by its responsiveness to different dimensions of the quality of life, ie by the extent to which self TTO varies with the dimensions. The analyses employed the 8 dimensions of the SF-36 and the 8 dimensions of the AQoL-8D. The former are well established in the literature (Ware & Sherbourne 1992). The latter were derived using similar psychometric methods as those which led to the SF-36 dimensions. They are described in Richardson, Elsworth et al. (2011). Both sets of dimensions are summarised in Box 4. Each of the 16 dimensions was standardised so that 0.00 equalled the worst level and 1.00 the best level described by the dimension.

The initial analysis was similar to the comparison with MAU instruments above. For each dimension respondents were ranked according to the dimension score. Average self TTO scores were calculated for each dimension score and the average regressed upon the dimension score. Results for 6 of the 8 dimensions of the SF-36 are shown in Figures 2a-2f and for the 8 dimensions of the AQoL-8D in Figures 3a-3h.

As in the analysis of MAU instruments, the number of individual observations varies. In particular, several of the SF-36 dimensions have a very small number of scores. Role function and Role emotion have only 5 and 4 levels respectively, and are not represented. The limited number of independent observations results in a very high level of aggregation of self TTO scores. The almost linear relationships in each case consequently have very high R^2 statistics. However, as previously, the chief interest is the 'b' coefficient in the regression which indicates the average responsiveness of self TTO to a change in the dimension level. Since each dimension is scaled from 0.00 to 1.00 the 'b' coefficient indicates the diminution in the average self TTO as the dimension changes from its best to its worst level.

Box 4 Dimensions of the HRQoL instruments used in the content analyses

	Instrument dimensions and items (abbreviations)	
	SF-36[(a)]	AQoL-8D[(b)]
Physical QoL	Physical function (Phys) 10 items: • vigorous/moderate activities, • lifting, • climbing stairs, • bending, • walking, • bathing	Independent living (Ind Liv) 4 items: • household tasks, • mobility, • walking and self-care
	Role physical (Role P) 4 Items: • time spent on work, • difficulty performing work	Senses (Sense) 3 items: • vision, hearing and communication
	Bodily pain (B Pain) 2 items: • degree of pain, • interference with normal work due to pain	Pain (Pain) 3 items: • serious pain, • interference with usual activities caused by pain
	General health (Gen H) 5 items: • perceptions of general health rating, • excellent health	Happiness (Happy) 4 items: • contentment, • enthusiasm, • happiness, pleasure
Mental QoL	Vitality (Vital) 4 items: • energy/tiredness	Coping (Cope) 3 items: • energy, • control, • coping
	Social functioning (Social) 2 items: • interference with normal and social activities	Relationships (Relation) 7 items: • relationship with family, friends, • social isolation, • intimate relationships, • community role
	Role limit emotional (Role E) 3 items: • work time, • work accomplished, • work less carefully than usual	Self-Worth (Worth) 3 items: • worthlessness/ confidence
	Mental health (MH) 5 items: • nervousness, • feel down, • felt calm/happiness	Mental health (Mental) 8 items: • depression/ sleep • anger • self-harm, • despair, • worry, • sadness, • tranquility
SWB	Satisfaction with Life Scale[(c)] 5 items: satisfaction with conditions and way of life, past and present	

Source: (a) Ware and Sherbourne (1992); (b) Richardson et al (2014); (c) Diener et al (1985)

Figure 2(a-f) Average self TTO (y) vs Dimensions of SF (x)

Figure 2(a) General Health

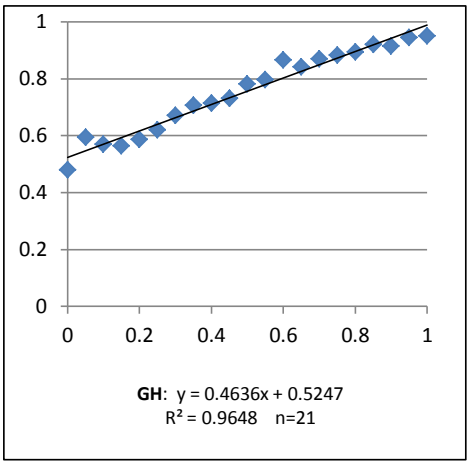


Figure 2(b) Vitality

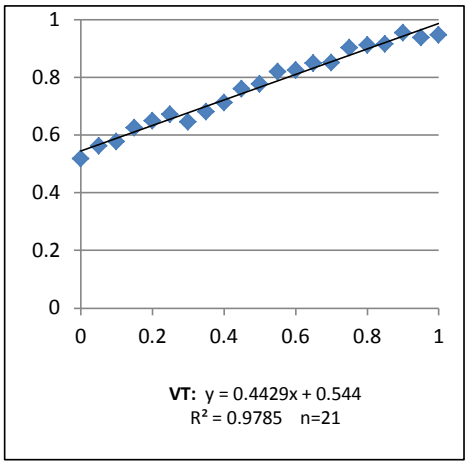


Figure 2(c) Physical Function

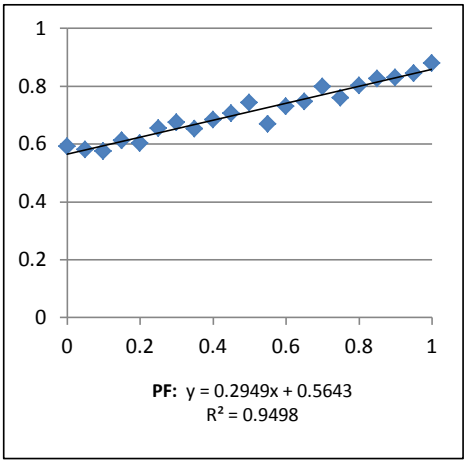


Figure 2(d) Social Function

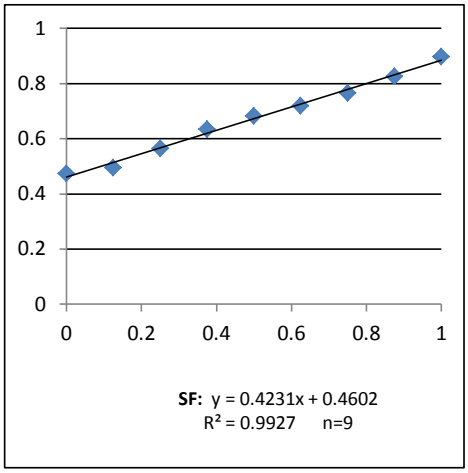


Figure 2(e) Body Pain

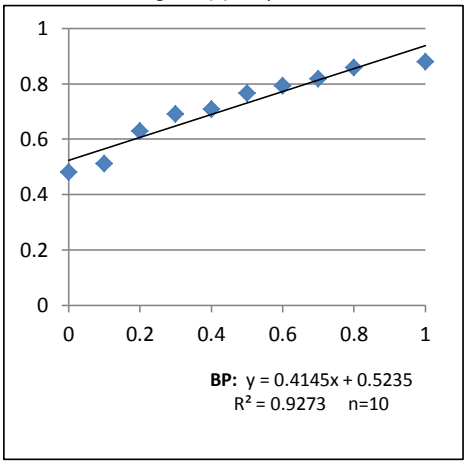


Figure 2(f) Mental Health

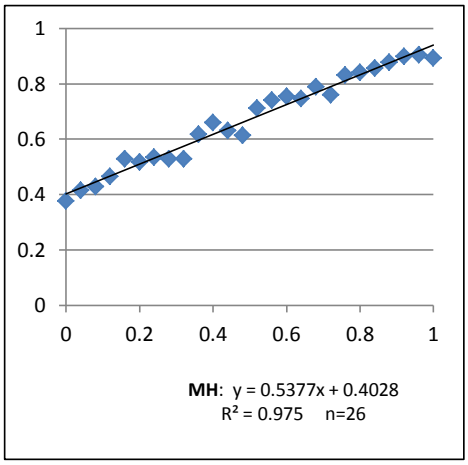
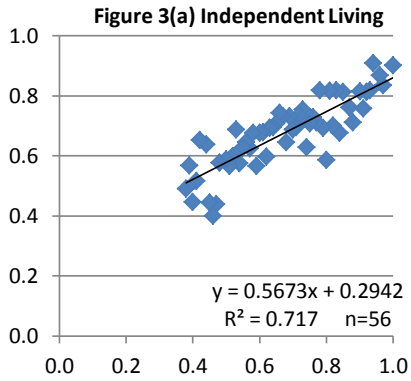
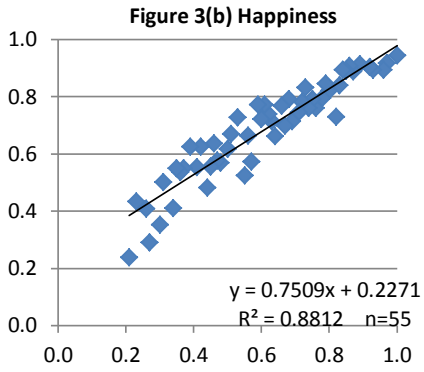
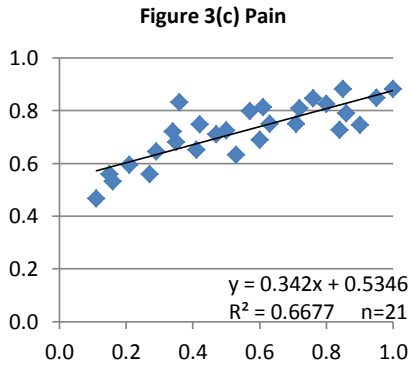
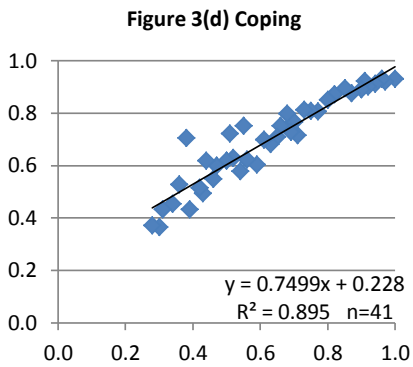


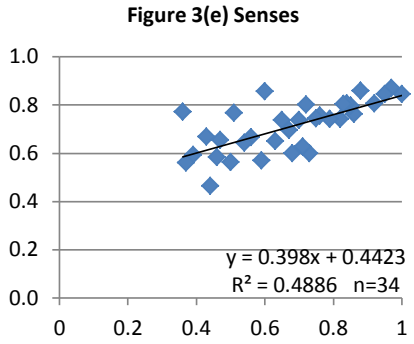
Figure 3 (a) to (h) Average self TTO (y) vs AQoL-8D dimensions (x)

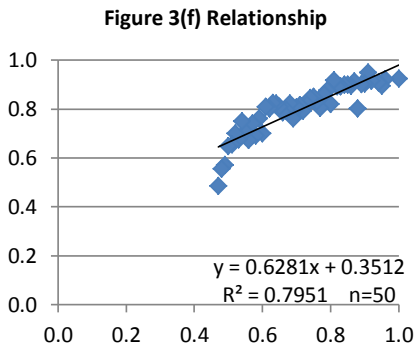


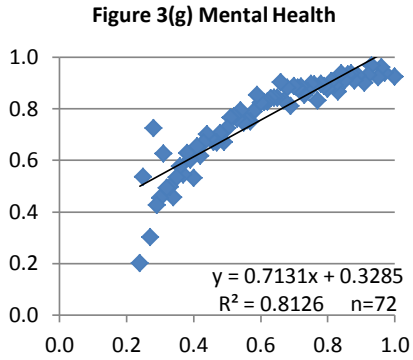












Coefficients are summarised in Table 9. The magnitudes of the coefficients are significantly greater for regressions including AQoL-8D dimensions suggesting that its conceptualisation of dimensions better describes the health states which induce people to trade quantity and quality of life. Both sets of results indicate that psycho-social dimensions are more closely related to self TTO than the physical dimensions. As judged by the b coefficient, SF-36 psycho-social dimensions rank 1, 3 and 4 in their importance. Only 'role emotion' – which relates to the effect of emotions on work, not general wellbeing – has a minor effect. Amongst the physical dimensions, general health – which measures perceptions of health and the change in health – has the largest effect. The remaining three physical dimensions all have a weaker association with self TTO than the three chief psycho-social dimensions. The pattern with the AQoL-8D dimensions is clearer. All psycho-social dimensions are more strongly associated with self TTO then any of the physical dimensions. Pain has a surprisingly weak association with self TTO in both sets of results.

Multivariate regressions were estimated using both sets of dimensions as the independent variables. Regressions were estimated with the full dataset and also with the subset of 7272 observations which excluded 748 individuals who would not trade any of their life. The two sets of results were effectively identical. Table 10 reports the latter regressions. These reveal the same pattern as the bivariate comparisons. Regressions are dominated by psycho-social variables. While general health – the individual's summary assessment of their health – is highly significant in the SF-36 equations, physical function is relatively unimportant and bodily pain is insignificant in the best fitting regression 4.

To determine whether the unexpected insignificance of pain was the result of a statistical artefact two regressions were estimated which dropped the two physical dimensions which might potentially mask the effect of pain, namely physical function (regression 2) and general health (regression 3).The coefficient on pain remained insignificant in the first but became statically significant but quantitatively small in the second regression. Neither pain nor senses has independent explanatory power in the AQoL-8D regressions.

Unlike the bivariate results, the AQoL-8D regressions did not identify mental health as having the greatest effect. The result is attributable to the correlation between mental health and other psycho-social variables and, in particular, happiness. The correlation reduces the partial association between mental health and self TTO. The statistical association, however, is an unreliable indicator of the direction of causation: mental health to happiness or happiness to mental health.

Table 9 Bivariate regression results: Self TTO upon dimensions of SF-36 and AQoL-8D

SF-36 dimensions					AQoL-8D dimensions				
Physical items Psycho-social					Physical items Psycho-social				
Dimensions	**Levels(1)**	**b**	**R2**	**rank**	**Dimensions**	**Levels(1)**	**b**	**R2**	**rank**
General Health (GH)	21	0.46	0.96	2	Independent living (IL)	56	0.57	0.71	6
Physical Function (PF)	21	0.29	0.95	6	Pain (Pain)	21	0.34	0.67	8
Bodily Pain (BP)	10	0.41	0.93	5	Senses (Sen)	34	0.40	0.49	7
Role physical (RP)	5	0.17		8	Psycho-social				
Psycho-social					Happiness (Hap)	0.55	0.75	0.88	2
Vitality (VT)	21	0.44	0.98	3	Coping (Cop)	41	0.749	0.90	3
Social function (SF)	9	0.42	0.99	4	Relationships (Rel)	50	0.62	0.80	5
Role emotion (RE)	4	0.20		7	Self-worth (SW)	48	0.66	0.88	4
Mental health (MH)	26	0.54	0.98	1	Mental health (MH)	72	0.713	0.81	1

(1) Regressions used average data for dimension categories with a minimum of 10 self TTO observations.

Table 10 Multiple regression results: Self TTO upon the dimensions of the SF-36 and AQoL-8D

	SF-36 Regressions								AQoL-8D Regressions				
Dependent variable[(1)]	**b**	**(t)**	**b**	**(t)**	**b**	**(t)**	**b**	**(t)**		**b**	**(t)**	**b**	**(t)**
Physical									**Physical**				
GH	0.16	(6.83)	0.17	(8.04)			0.16	(6.86)	IL	0.29	(7.74)	0.27	(10.56)
PF	0.05	(2.53)			0.08	(4.92)	0.05	(2.59)	Sen	-0.01	(ns)		
BP	-0.01	(ns)	0.01	(ns)	0.04	(2.23)			Pain	0.03	(1.50)		
RP	ns								Psycho-social				
Psycho-social									Hap	0.26	(6.28)	0.26	(6.28)
VT	0.06	(2.50)	0.06	(2.72)	0.14	(6.87)	0.06	(2.45)	Cop	0.11	(2.49)	0.11	(2.51)
SF	0.17	(8.38)	0.18	(9.04)	0.15	(8.19)	0.17	(8.49)	Rel	0.07	(1.89)	0.07	(1.89)
RE	ns								SW	0.12	(3.32)	0.12	(3.23)
MH	0.22	(8.62)	0.21	(8.29)	0.22	(9.45)	0.22	(8.72)	MH	0.09	(2.29)	0.10	(2.48)
Constant	0.33		0.36		0.35		0.34		Constant	0.09		0.07	
n[(2)]	7270		7270		7270		7270		n[(2)]	7272		7272	
Adj R^2	0.15		0.15		0.16		0.16		Adj R^2	0.15		0.16	

(1) See abbreviations used in previous table.

(2) The sample excluded 748 individuals who refused to trade any time. Regressions on the full sample produced almost identical results.

5 Test-Retest Survey

Methods: Two sets of individuals were recruited for the validation survey. Both were from the panel of CINT, the company which conducted the MIC survey. The first group were geographically close to Monash University. Each person completed the online Self TTO twice at approximately two week intervals and subsequently attended a face to face interview at the University. A single interviewer was employed. The Self TTO and additional VAS and conventional TTO questions were administered. The second group, recruited from across Australia similarly completed the Self TTO online at two week intervals. After a further two week period a telephone interview was conducted which included the Self TTO, and personal characteristics. People in the first group were given a voucher for $25. The second group were reimbursed $10 by internet PayPal (or by postal voucher).

The demographic characteristics of the pooled sample are given in Table 11. Two sets of results are presented in Tables 12 and 13 which report, respectively, mean responses and Pearson correlations. The first set of results are unedited. In Column 1 of Table 12 the mean responses differ significantly confirming the interviewer's reports that some individuals encountered significant difficulty with the exercise. A judgement was made that individuals whose results differed by more than 0.3 between the first and second stage (ie by more than 30 percent of their life expectancy) were unreliable and were excluded from the edited results. As shown in the second column of Table 12 this resulted in identical results for the test-retest and interview. Mean scores are significantly higher in the edited sample implying that those removed gave, on average, lower scores. From Table 13 the edits led to a reduction in the correlations between the results. This is not necessary indicative of unreliability as correlations tend to increase with the range of observations and, conversely, when observations are similar random error becomes relatively more important.

Re-estimation of Self TTO – MAU instruments regressions: The result in Table 12 indicates that unedited results are unreliable, at least at the individual level. A retrospective edit was therefore applied to the data. Observations were removed when the self TTO and the self-rated VAS included in the survey differed by more than 0.3: that is, the implied valuation of life differed by more than 30 percent. As reported earlier, the initial regressions reported in Figure 1(a) to 1(l) were repeated.

Revised results are however, unreliable. The ad hoc edits depend upon the assumption that the VAS is a satisfactory criterion and were applied retrospectively in the absence of an alternative method. However the VAS scale has its own specific properties. As noted earlier, its lower scores and more normal frequency distribution result in the deletion of high self TTO scores, when VAS is low. Regression of VAS upon the dimensions of the SF-36 and AQoL-8D reported in Appendix 4 indicate that 'health' is primarily interpreted as 'physical health'. This may well be the result of linguistic history rather than a person's perception of the elements of life which are of greatest importance to them.

Table 11 Characteristics of respondents to test-retest survey

		Age						Education			Total
		18-24	25-34	45-44	45-54	55-64	64+	School	TAFE	Uni	
Male	49	2	11	12	12	12	0	9	14	26	49
Female	61	1	11	15	11	21	2	13	27	21	61
Total	110	3	22	27	23	33	2	22	41	47	110

Table 12 Mean Self TTO

	Unedited		Edited	
	Mean	(se)	Mean	(se)
Web 1*	0.78	(0.03)	0.91	(0.01)
Web 2*	0.87	(0.01)	0.91	(0.01)
Interview	0.78	(0.03)	0.91	(0.01)
n	152		116	

* Web 1, Web 2 refer to the first and the second online result respectively

Table 13 Pearson correlation

	Web 1	Web 2		Web 1	Web 2
Web 1	1.00			1.00	
Web 2	0.77	1.00		0.25	1.00
Interview	0.75	0.75	1.00	0.41	0.45

6 Discussion

Possibly the most significant finding from the present research is the small percentage of respondents who were prepared to trade a significant part of their life expectancy in order to improve their quality of life. The finding was consistent in both the web based and interview based results. Subsequent analyses were based upon average results but this obscures the fact that the 'average' does not represent the results from the majority of respondents. In this respect the analysis here is no different from analyses elsewhere in the literature. The difference is the extent to which the average values differ from the majority view. The justification for the use of average values is the implicit assumption of utilitarianism: that utility should be maximised irrespective of its distribution. The maximum average value also maximises the total value.

The second major finding which follows from the first is that self TTO results in higher average utilities than those predicted by the majority of MAU instruments. Using unedited data from the web based algorithm, utilities predicted by the SF-6D and 15D are similar to self TTO utilities. By contrast with other MAU instruments these two instruments compress average scores and particularly for the most unwell. However, results from the test-retest study suggest that the removal of unreliable results is likely to increase average self TTO utilities so that SF-6D and 15D may also over-predict the importance of QoL.

Both of these findings reinforce an important theme in the literature: that the valuation of the QoL varies with the perspective and framing of the measurement instrument. The lowest values have been obtained using the Relative Social Willingness to Pay (RSWTP) instrument which was also created by the present authors (Richardson et al. 2013). The 'arm's length' or impersonal allocation of a budget between services which increase either the length or quality of life in this instrument results in values which favour QoL improvement. The 'quasi-personal' perspective of the usual TTO or standard gamble (or discrete choice experiment based upon hypothetical health states) leads to a decrease in the relative importance of the QoL. The fully personal perspective of the self TTO further decreases the relative importance of the QoL. The person trade-off (PTO) does not fit this pattern. While it adopts the same impersonal perspective as the RSWTP it generally produces high utilities thereby favouring lifesaving over quality improvement. Unlike the RSWTP the PTO varies the relative number of persons whose lives are saved or improved. The framing therefore increases the focus upon lifesaving and introduces an important distributional consideration. Either or both of these elements may contribute to the higher value placed upon life.

The third major finding, reported in the previous section, is that the self TTO obtained from the present algorithm has low test-retest reliability, at least among those willing to sacrifice a significant part of their life expectancy. While their removal increases the reliability of observations it does not necessarily improve the validity of average results in which the random positive and negative errors which cause unreliability may cancel out. It is, perhaps, unsurprising that individuals should be uncertain about their unwillingness to sacrifice a significant part of their life when the question is framed in a highly personal way, and this uncertainty is likely to increase with the size of the sacrifice.

Subject to these caveats the present results support a number of conclusions. First, the content of the 'self TTO' – the elements of the QoL which induce people to sacrifice life expectancy – is dominated by psycho-social dimensions. In the bivariate analyses mental health, as measured by both the SF-36 and AQoL-8D, has the largest effect upon self TTO. Physical function and pain – which dominate the content of the EQ-5D and HUI 3 – have comparatively small effects. In the multivariate analyses these results are accentuated. The partial effects of the main psycho-social dimensions exceed the partial effects of the physical dimensions with the exception of general health perceptions which are included in the physical component of the SF-36. Pain only enters the SF-36 regressions if general health is removed and its quantitative effect, like the effect of physical function, is small. Overall these results imply that the physical dimensions which have been given greatest prominence in the analyses of QoL to date do not correspond with the dimensions which are of greatest importance when people make personal trade-off decisions.

The content of instruments – the dimensions of the QoL which explain variation in their scores – is a separate question from the scale used to quantify change. It is possible for an insensitive instrument to inflate numerical differences or, conversely, for a sensitive instrument to compress them. A major motivation in the development of the self TTO instrument was to develop an independent method for evaluating an instrument's scale and to determine whether or not it was consistent with the 'strong interval property': the requirement that a percentage change in utility is equally valued as the same percentage change in life expectancy. Using the self TTO as a criterion, the strong interval property implies that the incremental change in the utility of an MAU instrument would equal the change in the self TTO. From both the comparison of utilities by disease group and from the regression of MA-utilities upon the self TTO the most successful instrument was the SF-6D followed by the 15D, AQoL-8D, EQ-5D and HUI 3.

Using unedited data the SF-6D, on average, almost exactly achieves the strong interval property. Comparison suggests that the other instruments exaggerate the importance of quality relative to length of life. Editing data alters these relationships but the retrospective edit is itself problematical. However the change reinforces the conclusion that MAU instruments exaggerate the importance of QoL. In each case the regression coefficient, b, is reduced implying the need for greater compression of the MA-utilities to achieve the same result as the self TTO.

7 Conclusion

The self TTO is a theoretically appealing but experimental instrument. It embodies the perspective required by theoretical welfare theory: the perspective of the person affected. The evidence from the experimental application of the instrument strongly suggests that the current MAU instruments undervalue the significance of psycho-social dimensions of health but, overall, exaggerate the importance of the quality relative to the length of life. In this respect the results are most consistent with those produced by the person trade-off instrument. However, the test-retest results here imply that further developmental work is needed to increase the instrument reliability.

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Appendix 1 Avatar script

Hi there. I'm going to ask you a series of questions about various health states, and I'm here to help make it clear and easy for you to understand.

You can turn up the volume on your computer and listen to me speak or you can read what I'm saying on screen. Are you ready to get started?

- Let's begin

How does your present health compare with the best health possible?

The best health possible means you have an extraordinary sense of wellbeing with NO symptoms or impediments at all. Your *physical* health is excellent - you have no pain or discomfort. Your hearing, vision and speech are perfect. Your energy, strength and flexibility are at their peak. *Mentally* you are happy, enthusiastic, and confident and you have a high self-esteem. You're never sad, depressed, worried or anxious. And to top it off, you have excellent *social* and *family* relationships. It simply can't get any better than this.

So how does you present health compare?

I believe my present health is…

- the best health possible
- *less than* the best health possible

(if the best health possible….)

So you believe that living in your present health is the same as living in the best possible health. Wow really? Your health couldn't get any better? You're at the peak of human performance? I'm in the best possible health, but I'm a young avatar and I'm not real. Please confirm if you believe you have the best health possible.

- That's right, I have the best health possible.
- I guess my health could be better than it is.

Great. Welcome to the Human Race. Now, I want you to imagine that your present health (which is less than the best possible) will remain exactly the way it is and then you will die a sudden death 10 years from now in the year 2022. This is a hypothetical scenario so it's not important *how* you die - it's not even the focus of this study. What IS important is that your present health will not get any better or worse in that time - there won't be any improvement or deterioration. Just you, in your present health, as is, for the next 10 years.

Got it?

Yes

Okay. Now, would you be willing to exchange these final 10 years in your present health for a shorter period of time living in the *best health possible*?

For example, would you be willing to exchange these 10 years in your present health for 9 years and 11 months in the best possible health, effectively choosing to live 1 month less.

- Yes, I'd be willing to exchange these 10 years in my present health for 9 years and 11 months living in the best health possible.
- No, I would prefer to live the full 10 years in my present health.

So you wouldn't even give up one month to experience the best possible physical, social, mental and emotional health?

- That's correct, I wouldn't give up any time at all
- Actually, I would be willing to give up 1 month

Well now I'm going to be cheeky and ask you another question.

Would you be prepared to exchange these final 10 years in your present health for 2 years living in the best possible physical, social, mental and emotional health - effectively living 8 years less.

- Yes, I'd be willing to exchange these final 10 years in my present health for 2 years living in the *best* possible mental, physical and social health.
- No, I would prefer to live the full 10 years in my present health.

Okay, so you place *some* value on living in the best possible health because earlier you said you'd give up a month of the 10 years, but clearly there's a limit to how much time you'd give up to experience that extraordinary health. So what *is* your limit?

I'd be willing to forego living in my present health for these final 10 years if I could have…

1	2	3	4	5	6	7	8	9	10

…years in the *best* possible health instead.

OR

- I'm unwilling to give up a full year.

I am willing to trade 1 year in exchange for 9 years of excellent health

So you value excellent health, but not so much that you'd exchange 8 years of life for it. Well then, how much time would you be willing to exchange?

Then what's the maximum amount of time you're willing to give up? in order to live in excellent health.

<1 year and live 9 in excellent health etc>

Okay so let's recap. You're saying that you would be prefer to live for 2 years in the best possible health, which would mean dying 8 years earlier, as opposed to living these final 10 years in your present health.

But is that the *most* time you'd be willing to give up? What about another 6 months? After all this is the *best* physical, social, mental and emotional health possible.

- Yes, I'd be willing to forego living in my present health for 10 years if instead, I could have 2 years and 6 months in the best health possible.
- No. I'm not willing to give up any more time.

< Back

Options to record…
<lessthan9.html> 9/1
<lessthan8.html> 8/2
<lessthan7.html> 7/3
<lessthan6.html> 6/4
<lessthan5.html> 5/5
<lessthan4.html> 4/6
<lessthan3.html> 3/7

Okay so let's recap. You're saying that you would be prefer to live for 2 years in the best possible health, which would mean dying 8 years earlier, as opposed to living these final 10 years in your present health.

But is that the *most* time you'd be willing to give up? What about another year? After all this is the *best* physical, social, mental and emotional health possible.

- Yes, I'd be willing to forego living in my present health for 10 years if instead, I could have 1 years in the best health possible.
- No. I'm not willing to give up any more time.

< Back

Okay so let's recap. You're saying that you would be prefer to live for 9 years and 11 months in the best possible health, which would mean dying 1 month earlier, as opposed to living these full 10 years in your present health.

But, is that the most time you'd be willing to give up? What about giving up a little more time. After all this is the best physical, social, mental and emotional health possible.

I'd be willing to forego living in my present health for 10 years if instead, I could have…

- 9 years and 11 months
- 9 years and 9 months
- 9 years and 6 months
- 9 years and 3 months
- 9 years

…in the best health possible.

Submit <signoff.html>

Well that's all from me. Thanks for your careful consideration of these questions. You've reached the end of the survey but if you'd like to leave any feedback on how we can improve it, feel free to do so below. Have a great day.

Feedback…
(box)

Submit.

UNUSED

I'd be willing to forego living in my present health for 10 years if I could have…

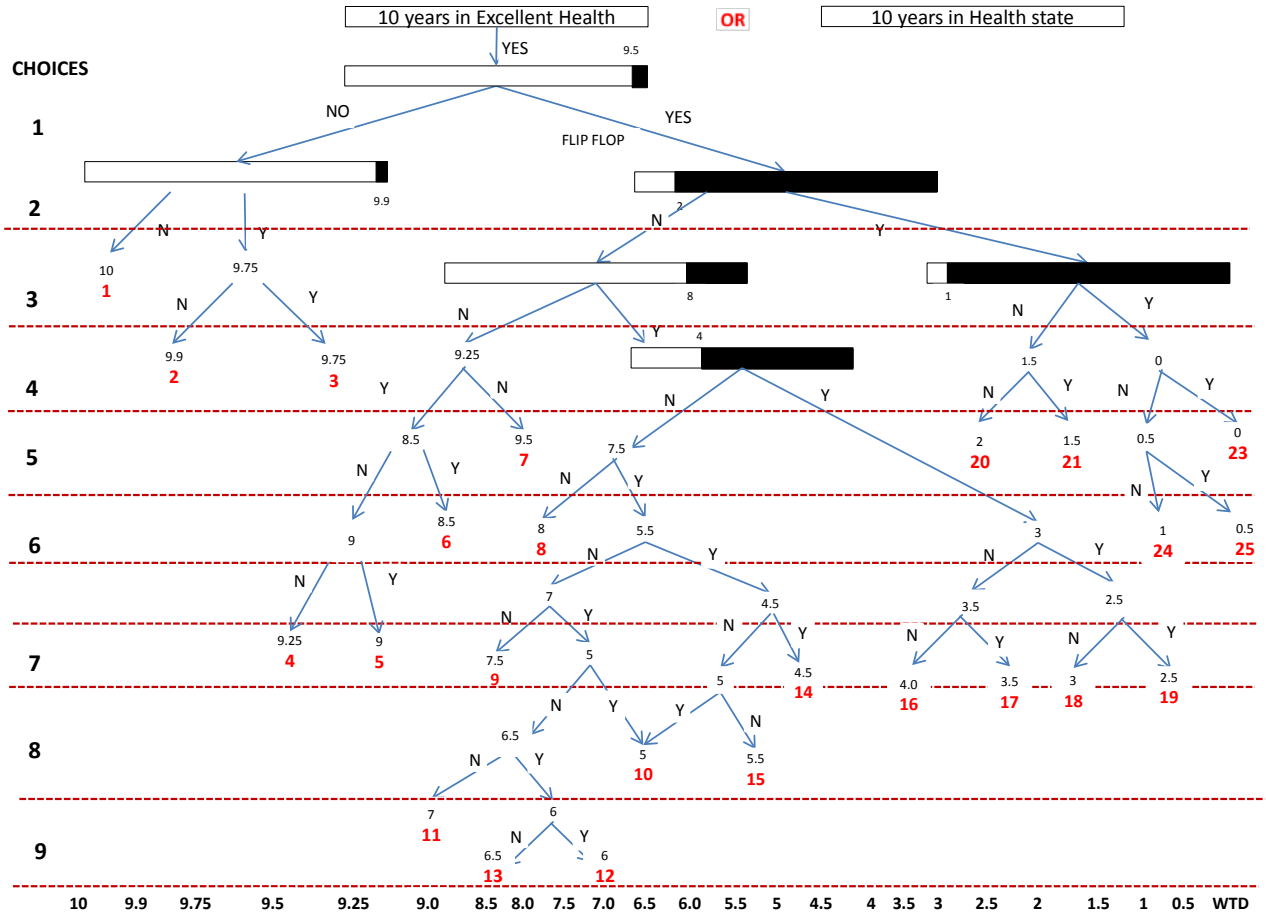
2 yrs	2 yrs and 6 mths	3 yrs	3 yrs and 6 mths	4 yrs
	•	•	•	

…in the best possible health instead.

OR

- I'm unwilling to choose any less than 3 years in the best health possible.

Appendix 2 The options decision tree



Appendix 3 Frequency Distribution of Self TTO (n=8023)

Range	Number	%
1.00	749	9
95-100	3460	43
90-94	1241	15
80-90	146	2
70-80	667	8
60-70	426	5
20-60	190	2
<20	699	9
0	443	6
	8023	100

Appendix 4 Content of VAS *vs* self TTO

Beta coefficients from regression upon SF-36 health dimensions (t statistic)

	SF-36 dimensions		Content[1]	
Dimension of SF-36	**VAS**	**Self TTO**	**VAS**	**Self TTO**
General Health	0.52 (47.2)	0.13 (8.5)	0.55	0.26
Physical functioning	0.12 (11.5)	0.03 (2.1)	0.13	0.06
Bodily pain	ns	ns	ns	ns
Role physical	ns	ns	ns	ns
Sum Physical	0.64[2]	0.16[2]	0.68	0.32
Vitality	0.10 (8.4)	0.07 (3.9)	0.11	0.14
Social function	0.11 (5.6)	0.12 (7.4)	0.12	0.25
Role emotional	ns	ns	ns	ns
Mental health	0.09 (7.6)	0.14 (8.1)	0.09	0.29
Sum psycho-social	0.30[2]	0.33[2]	0.32	0.68
R^2	0.59	0.48		

[1] Beta coefficients scaled to sum to 1.00. This permits comparison of the *relative* (not absolute) importance of each dimension.

[2]. Summed coefficients indicate the effect of a standard deviation change in all of the physical dimensions (1-4) or all of the psycho-social dimensions (5-8).

Appendix 5 An Alternative Edit Procedure

Limits were placed upon the discrepancy between a person's PWI score for their satisfaction with their health – PWI (H) – and Self TTO values as defined below:

X = 0.6 + 0.6 PWI (H)

delete observations where Self TTO > X

Y = 0.1 + 1.125 Self TTO

delete observations where PWI (H) > Y

The resulting scattergram of observations are shown below and the re-estimated regression of Self TTO upon MA utilities over page.