



## Risk attitudes of people with ‘manageable’ chronic disease: An analysis under prospect theory



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### ABSTRACT

Health promotion interventions can be improved using methods from behavioural economics to identify and target specific decision-making biases at the individual level. In this context, prospect theory provides a suitable framework within which decision-making processes can be operationalised. Focusing on a trade-off between health outcomes and behaviour change incurred by chronic disease management (lifestyle change, or ‘self-management’), we are the first to measure the risk attitudes and quantify the full utility function under prospect theory of a patient population. We conducted a series of hypothetical elicitations over health outcomes associated with different self-management behaviours from a population of individuals with or without ‘manageable’ chronic disease (n = 120). We observed risk aversion in both the gain and the loss domains, as well as significant loss aversion. There seems to be an age effect on risk attitudes in this context, with younger people being on average less risk averse than older people. Our work addresses a need to better understand these decision-making processes, so that behaviour change interventions tailored to specific patient populations can be improved.

### 1. Introduction

People are constantly faced with choices under conditions of uncertainty. In the health domain, for example, patients have to decide whether to take a treatment or not, considering both its benefits (health outcomes) and costs (side effects), which may carry significant uncertainty. With the progress of medicine, an increasing number of chronic diseases have become ‘manageable’, leading to new types of trade-offs. Type 2 diabetes mellitus (T2DM; the non-insulin dependent form of the disease) is a good example of this: if well controlled, people with T2DM can expect health outcomes similar to the average person (i.e. broadly equivalent life expectancy and quality of life) (Lutgers et al., 2009; Redekop et al., 2002). However, having good control of the disease requires adhering to a certain number of lifestyle changes (‘self-management of the disease’, including adopting a healthy diet, engaging into regular physical activity, being adherent to medications, etc.) (American Diabetes Association., 2017; Shrivastava et al., 2013; Norris et al., 2001) and in practice a significant proportion of patients fail to change their behaviour once diagnosed (Peyrot et al., 2005; Bodenheimer et al., 2002). As a result, people who do not change their

behaviour may have fewer commitments in their daily life but may subsequently be more likely to suffer from complications that could have been avoided.

In this context, there is a need for more effective interventions that encourage people with chronic disease to change their behaviour (Rouyard et al., 2017). Over the past ten years, there has been increasing interest in using concepts and methods from behavioural economics to inform health interventions (see e.g. Luoto and Carman, 2014; Loewenstein et al., 2012; Petry et al., 2013). Located at the interface of decision theory, economics and psychology, behavioural economics assumes that normative theories of choice provide an unrealistically rational account of how people make decisions (Waters et al., 2013; Sutton, 2001) and promotes the development and application of more descriptive theories of choice for policy-making purposes. Known as nudges, interventions based on behavioural economics aim to target systematic biases (or ‘irrationalities’) identified in people’s decision-making processes to ‘nudge’ people towards a given recommended behaviour (Thaler and Sunstein, 1999). For example, people tend to discount delayed rewards, such as avoiding cancer or heart disease, relative to more immediate, smaller rewards, such as

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having a cigarette or an extra dessert now ('present biasedness'). In a recent study, Mørkbak et al. (2017) showed that present biasedness was associated with earlier onset of diabetes and lower ability to manage chronic disease. This supports the development of interventions aiming to mitigate the effect of this bias (e.g. incentives or monetary-based rewards) to increase adherence to self-management in these populations. Such interventions have shown promising results in encouraging weight loss (Volpp et al., 2008), enhancing exercise (Petry et al., 2013), or improving medication adherence (Petry et al., 2015).

We aim to contribute to this literature by exploring the risk attitudes of people facing (risky) behavioural choices associated with chronic disease management. Risk attitudes is known to play a key role in the decision-making process (Weber and Milliman, 1997; Sitkin and Weingart, 1995) and risk seeking behaviour could explain, at least partly, non-adherence to self-management behaviour. In this context, prospect theory (PT) (Kahneman and Tversky, 1979) provides a good, tractable way of operationalising people's decision-making processes. It allows exploring risk attitudes together with three decision-making biases potentially helpful to design better targeted nudge interventions: reference point (RP) dependence (people evaluate outcomes relative to an RP, and then classify them as gains and losses), probability weighting (people tend to overweight less likely events and underweight more likely ones) and loss aversion ('losses loom larger than commensurate gains', i.e. the pain of losing is psychologically more powerful than the pleasure of gaining) (see e.g. Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). For monetary outcomes, numerous empirical studies have shown the existence of PT biases. For health outcomes, however, the literature is still sparse. This is an issue since significant differences exist between health utility and utility for money (Attema et al., 2013). This may partly explain why nudges aiming to increase adherence to self-care behaviours – which rely on biases identified with monetary outcomes – have shown mixed results so far (see Kullgren et al., 2017 for a review in T2DM populations). To our knowledge, only two studies have measured utility under PT with health outcomes. First, focusing on utility for life duration, Attema et al. (2013) found evidence of loss aversion and risk aversion with respect to both gains (slightly concave utility) and losses (concave utility) in a study conducted on a student population. Evidence of probability weighting, more pronounced in the gain domain, was also reported. Second, a recent study conducted on a general population sample found similar trends with respect to the utility for quality of life (QoL) (Attema et al., 2016). These findings challenge, in part, what is usually observed with monetary outcomes. In particular, they contradict the S-shaped utility function characteristic of PT, due to concave utility for losses.

In this study, we aim to quantify the full utility function under PT (i.e. utility parameters and loss aversion coefficient) of a population that includes people living with a chronic condition, using outcomes that include both dimensions of health utility: life duration and QoL. Conducting the study on patients is crucial to better understand specific decision-making processes that will help design tailored nudge interventions. This study is the first to do so. Using a recent method of utility elicitation under PT in the health domain, we measure people's risk attitudes by investigating their trade-offs between health outcomes associated with different self-management behaviours. More specifically, we analyse risky decisions through the lens of the three decision-making biases embedded into PT: a) RP dependence; b) probability weighting; and c) loss aversion.

Our results show that people express a high degree of risk aversion, both in the gain and in the loss domains, and significant loss aversion. This is in contrast with the findings using monetary outcomes and suggests that the role of the RP may be less crucial for health than it is for money. There seems to be an age effect on risk attitudes, with younger people being on average less risk averse than older people. Finding evidence of risk aversion for both gains and losses in this study suggests that risk seeking behaviour does not explain lack of adherence to self-management in T2DM populations. Our results support the

design of interventions that raise awareness of diabetes-related health risks and take advantage of people's loss aversion.

## 2. Method

Our method follows Attema et al. (2013)'s semi-parametric method of utility elicitation in the health domain. It uses certainty equivalents (CEs) to measure the parameters of a specific utility function (exponential parametric family). CEs are elicited through a series of choices over binary prospects involving different life durations. However, we expand on this work by adding a QoL dimension to the outcomes, so that preferences based on more realistic scenarios for health-related behaviour change can be captured. The use of quality-adjusted life years (QALY) outcomes allows quantifying similarly both the disutility of engaging in self-care behaviour and the disutility of suffering from disease-related complications.

### 2.1. Model

Let  $(p, x; y)$  denote a binary prospect that gives outcome  $x$  QALYs with probability  $p$  and outcome  $y$  QALYs with probability  $1 - p$ . Gain prospects [loss prospects, mixed prospects] imply that  $x \geq y \geq 0$  [ $x \leq y \leq 0$ ,  $x > 0 > y$ ]. According to PT, evaluation of prospects can be represented by the following equations, where  $w^+(p)$  [ $w^-(p)$ ] is the decision weight associated with the fixed probability  $p$  in the gain [loss] domain, and  $u(x)$  [ $u(y)$ ] denotes the utility associated with the outcome  $x$  [ $y$ ]:

$$PT(p, x; y) = w^+(p) \times (u(x) - u(y)) + u(y) \text{ for gain prospects;} \quad (1)$$

$$PT(p, x; y) = w^-(p) \times (u(x) - u(y)) + u(y) \text{ for loss prospects, and;} \quad (2)$$

$$PT(p, x; y) = w^+(p) \times u(x) + w^-(1 - p) \times u(y) \text{ for mixed prospects.} \quad (3)$$

The semi-parametric method entails three stages. First, eliciting CEs of a series of two-outcome gain prospects (different outcomes, but same probability for all prospects) allows us to identify the utility function for gains and the decision weight  $w^+(p)$ . By assuming PT and a particular parametric shape of the utility function, it is indeed possible to estimate the parameters of the function and the decision weight of the probability that best fit the elicited data. Second, the same steps need to be performed in the loss domain. Finally, both utility functions can be connected through the elicitation of the maximum loss amount that a subject is willing to accept in a mixed prospect including one of the gain outcomes used in the first stage. This enables estimation of the loss aversion coefficient  $\lambda$ , allowing comparison between gain utilities and loss utilities. Details are provided in the following subsections. This semi-parametric method has several advantages compared to fully and non-parametric methods. Firstly, measurements are not confounded by assumptions about the shape of the probability weighting function. Secondly, it is less time-consuming for the respondent because fewer questions are needed to elicit the CEs (Abdellaoui et al., 2008).

### 2.2. Elicitation of utility parameters and decision weights

The method assumes that observable  $U$  is a composition of  $\lambda$  and a basic utility  $u$ , with:

$$U(x) = \begin{cases} u(x) & \text{if } x \geq 0 \\ \lambda u(x) & \text{if } x < 0 \end{cases} \quad (4)$$

Following Attema et al. (2013), we consider the exponential family of utility functions for both utilities of gains and losses:

$$\begin{cases} u(x) = \frac{1 - \exp(-\gamma x)}{\gamma} \text{ for gains;} \\ u(x) = \frac{\exp(\delta x) - 1}{\delta} \text{ for losses;} \end{cases} \quad (5)$$

With risk aversion coefficients  $\gamma, \delta \neq 0$ . For  $\gamma, \delta = 0, u(x) = x$ .

For each prospect  $i$  in the gain [loss] domain, we elicit a  $CE_i$  such that the respondent is indifferent between gaining [losing]  $CE_i$  QALYs for certain and the prospect that provides a 50% chance of gaining [losing] a higher amount  $x_i$  QALYs and 50% chance of gaining [losing] a lower amount  $y_i$  QALYs. Then, assuming PT and exponential utility functions, this indifference can be described by the following equations:

• Gains:

From equation (1) and equation (5), we obtain:

$$\frac{1 - \exp(-\gamma CE_i)}{\gamma} = \omega^+ \cdot \left( \frac{1 - \exp(-\gamma x_i)}{\gamma} - \frac{1 - \exp(-\gamma y_i)}{\gamma} \right) + \frac{1 - \exp(-\gamma y_i)}{\gamma}; \quad (6)$$

with  $\omega^+ = w^+(1/2)$ .

Solving this expression for  $CE_i$  gives the following regression equation:

$$CE_i = - \frac{\ln[\omega^+ \cdot (\exp(-\gamma x_i) - \exp(-\gamma y_i)) + \exp(-\gamma y_i)]}{\gamma} \quad (7)$$

From equation (7), it is possible to estimate both the utility function parameter  $\gamma$  and the decision weight  $\omega^+$ , through non-linear least squares.

• Losses:

From equation (2) and equation (5), we obtain:

$$\frac{\exp(\delta CE_i) - 1}{\delta} = \omega^- \cdot \left( \frac{\exp(\delta x_i) - 1}{\delta} - \frac{\exp(\delta y_i) - 1}{\delta} \right) + \frac{\exp(\delta y_i) - 1}{\delta}; \quad (8)$$

with  $\omega^- = w^-(1/2)$ .

Solving this expression for  $CE_i$  gives the following regression equation:

$$CE_i = \frac{\ln[\omega^- \cdot (\exp(\delta x_i) - \exp(\delta y_i)) + \exp(\delta y_i)]}{\delta} \quad (9)$$

Similarly, from equation (9), it is possible to estimate both the utility function parameter  $\delta$  and the decision weight  $\omega^-$ , through non-linear least squares.

2.3. Elicitation of loss aversion parameter

We estimate the loss aversion coefficient  $\lambda$  by determining the loss outcome  $L^*$  for which the participant is indifferent between a prospect giving a 50% chance of gaining an outcome  $G^*$  and a 50% chance of losing the outcome  $L^*$ , and the status quo:

$$(1/2, G^*; L^*) \sim 0 \quad (10)$$

From equation (3), this mixed prospect gives:

$$\omega^+ \cdot U(G^*) + \lambda \cdot \omega^- \cdot U(L^*) = 0 \quad (11)$$

Which, in terms of the exponential utility function; translates into:

$$\omega^+ \cdot \frac{1 - \exp(-\gamma G^*)}{\gamma} + \lambda \cdot \omega^- \cdot \frac{\exp(\delta L^*) - 1}{\delta} = 0 \quad (12)$$

Solving this expression for  $L^*$  gives the following regression equation:

**Table 1**  
List of stimuli used in the experiment (years of life [QALYs]).

	j = 1	j = 2	j = 3	j = 4	j = 5	G*
x	6 [4.5]	10 [7.5]	12 [9]	15 [11.25]	15 [11.25]	10 [7.5]
y	0 [0]	0 [0]	0 [0]	5 [3.75]	9 [6.75]	

$$L^* = \frac{\ln \left[ 1 - \left( \frac{\omega^+ \cdot \delta}{\omega^- \cdot \lambda} \right) \cdot \frac{1 - \exp(-\gamma G^*)}{\gamma} \right]}{\delta} \quad (13)$$

3. Experiment

3.1. Stimuli

We aim to elicit preferences, both in the gain and loss domains, when the outcomes vary in terms of both life duration and QoL (see 3.3.c). As a result, participants make choices over outcomes quantified in terms of QALYs.

The utility functions for both gains and losses were elicited by the use of 5 CE questions each and one outcome  $G^*$  was used to measure loss aversion (see Table 1). Importantly, we introduced an RP of living 20 more years. The length of the RP was the result of a trade-off between two elements: tractability and realism. On the one hand, a large RP was needed to allow variation in prospects over a sufficiently wide range of health outcomes. Setting up an RP of 20 years allowed us to design loss prospects involving the potential loss of up to 15 years of life. We decided not to design loss prospects involving the loss of up to 20 years of life (i.e. the totality of the RP), in order not to induce any psychological stress or negative emotional reaction. The prospect of dying ‘immediately’, that may have provoked anxiety, was thus ruled out as an option. On the other hand, because T2DM rarely occurs before the age of 50, the average life expectancy of our population did not provide us with much leeway to adopt a large RP. For the sake of realism, we decided to exclude individuals aged above 60 from the study (see 3.2). In this way, setting up a RP of 20 years led to the best-case scenario of older participants reaching the maximum age of 95 years (60 years old + RP of 20 years of life + potential gain of 15 years of life). Section 3.3.b provides more details on the elicitation procedure.

3.2. Participants

The sample includes 120 individuals between 30 and 60 years of age. Sixty participants were living with T2DM, and 60 participants had no diagnosis of T2DM or any other chronic disease. T2DM is a good example of a manageable chronic disease: it often requires multiple drug therapies, frequent monitoring of risk factors and regular health care contacts, and good control is associated with better health outcomes (life expectancy and QoL) (American Diabetes Association., 2017; Shrivastava et al., 2013; Norris et al., 2001). This study received ethics approvals from the competent UK research ethics committees [ref. 16/NE/0203].

3.2.1. T2DM group

The inclusion criteria were: 1) aged between 30 and 60; 2) diagnosed with T2DM; 3) willing and able to give informed consent for participation in the study. The exclusion criterion was: non-English speaker. The rationale behind the lower age limit (30) is that T2DM is rarely diagnosed before that age, while the upper age limit (60) was set for experimental reasons, due to the RP of 20 years: the older the subject, the more unrealistic the hypothetical scenarios used to elicit risk preferences and the higher the risk of elicitation bias (see Appendix A). Subjects in this group were familiar with the daily management of T2DM (they had been informed and trained at diagnosis).

### 3.2.2. Control group

We formed a control group to examine risk preferences and PT parameters in a comparable population who is not concerned with the daily management of a chronic disease. The inclusion criteria were: 1) aged between 30 and 60; 2) not diagnosed with T2DM or any other chronic disease; 3) willing and able to give informed consent for participation in the study. The exclusion criterion was: non-English speaker.

### 3.3. Procedure

#### 3.3.1. Recruitment

Subjects were recruited at a local surgery practice in the UK. Control participants were patients between 30 and 60 coming to the surgery practice for minor health issues and who kindly agreed to participate in the study. In order to balance the sample in terms of age and gender, we tried to recruit a similar proportion of subjects below and above 50 as well as a similar proportion of men and women in both groups. Because T2DM usually appears in the late 50/early 60 years of age, a major challenge of the study was to find ‘young’ eligible people (i.e. aged below 50) diagnosed with the disease. Similarly, it was more difficult to recruit female participants than male participants in the T2DM group because of the higher prevalence of T2DM in the male population.

After receiving information about the study from their general practitioner (GP), consenting participants were presented with the online questionnaire during a one-to-one interview with an experimenter. The study took place in a private area of the surgery practice. The experimenter carefully explained each scenario and made sure that the participant understood the instructions and the questions. It was made clear that there were no right or wrong answers. Each subject received a modest monetary incentive (£10) to participate in the study, as is commonly done in the field. The incentive was given at the end of the survey, independently of the answers of the participant.

#### 3.3.2. Questionnaire

A questionnaire specifically designed to elicit participants' risk preferences was developed in collaboration with both health professionals and patients. We adapted existing questionnaires (Abdellaoui et al., 2008) to fit the population and outcomes of interest. In particular, we took into account the suggestions of a small group of patients (4 volunteers) who were asked to provide feedback on user-friendliness and comprehensibility. Indifferences (i.e. the CEs) were elicited through a series of binary choices. Each binary choice corresponded to an iteration in a bisection process (see example in Table 2). In each choice participants were faced with two prospects, labelled ‘option A’ and ‘option B’, where ‘option A’ was always riskless. Based on our group of volunteers' feedback on the graphical features of the questionnaire, prospects were displayed as ‘smiley chains’, with each smiley symbolising a year of life, and accompanied by a short description (see example in Fig. 1). A green smiley represented a year lived with perfect

QoL (100%), a yellow smiley a year lived with good QoL (75%), and a red smiley a year lived with moderate QoL (50%). The order of the 5 CE questions was randomised to avoid a potential order effect (for both gains and losses). Moreover, to control for response errors and check the reliability of collected data, we repeated the first iteration after the final iteration for 5 CE questions ( $j = 3$  and  $j = 4$  for both gains and losses, and the mixed prospect) (Abdellaoui et al., 2008).

In Table 2, the prospect that is chosen in each iteration is printed in bold. Starting values in the iterations were always selected so that prospects had equal expected value. Depending on the choice made, the certain outcome was increased or decreased (but was always an integer). The method resulted in an interval within which the indifference value should lie. The midpoint of this interval was taken as the indifference value. In this first example, we started with prospects whose expected value was 7.5 QALYs. The indifference value elicited for the sure outcome was 4.9 QALYs, implying risk aversion.

#### 3.3.3. Scenarios

The QoL dimension that we consider is a broad notion of health-related QoL, which describes the three hypothetical scenarios used to design the prospects. Each scenario is attributed with a score, expressed in percentage points, on a scale ranging from 0 (worst possible health-related QoL) to 100 (best possible health-related QoL), based on a description of the QoL associated with the scenario in question. The scenarios and their values were designed according to four criteria. First, the scenarios should depict significantly different QoL scenarios, in order to a) benefit from sufficient leeway to design the prospects; and b) create clear differences in the mind of participants. Second, the QoL scores should be as easy to understand as possible for the participants. Third, the QoL scores should also be as realistic as possible. Finally, the scenario descriptions should not be over-precise, in order to avoid ‘rating biases’. We wanted the participants to imagine living with the QoL score we set and to use a precise health state description to illustrate this score (e.g. ‘living with a QoL of 50% corresponds to living with a lower extremity amputation’) would very likely create a bias, depending on how the person actually rates the QoL of living with an amputation. Such personal ratings could be much lower or higher than 50%, and studies such as Huang et al. (2007) have shown that the scores patients with T2DM attribute to a given health state can be widely heterogeneous.

Scenarios and corresponding scores are displayed in Table 3. We used QoL scores drawn from a study which aimed to quantify patients' utilities (i.e. measuring preferences) for the full array of diabetes-related complications and treatments (Huang et al., 2007). For scenario 1 (‘behaviour change; no complication’), we used the utility attributed to life under ‘conventional glucose control’ (i.e. following a recommended self-management behaviour but possibly experiencing side effects due to medications) and rounded it down to 75%. For scenario 3 (‘no behaviour change; complication’), we used the utility attributed to life with a ‘lower extremity amputation’ and rounded it down to 50%. These scores (75%, 50%) reflect a compromise which satisfies each of the four criteria mentioned before and quantify the (dis)utilities inherent in the three scenarios (and thus allow the elicitation of CEs) but are not intended to generate empirically grounded QALYs.

### 3.4. Analysis

#### 3.4.1. CEs and risk attitudes

A participant was classified into the risk averse [risk neutral, risk seeking] category for gains [losses] if he or she showed risk aversion [risk neutrality, risk seeking] for at least four out of five CEs. Otherwise, the person was classified into the mixed category for gains [losses]. This allowed us to take into account a small margin of error in the responses. Because the data were not normally distributed, we performed non-parametric statistical tests. Within-subjects comparisons were made using Wilcoxon signed-rank tests and between-subject comparisons

**Table 2**  
An illustration of the bisection method (gains;  $j = 4$ ).

Iteration	Offered choices in elicitation of G4	Expected value (QALY)
1	<b>10 years (75%)</b> vs. [ $\frac{1}{2}$ , 15 years (75%); 5 years (75%)]	7.5
2	5 years (75%) vs. [ $\frac{1}{2}$ , <b>15 years (75%); 5 years (75%)</b> ]	3.8
3	<b>8 years (75%)</b> vs. [ $\frac{1}{2}$ , 15 years (75%); 5 years (75%)]	6.0
4	6 years (75%) vs. [ $\frac{1}{2}$ , <b>15 years (75%); 5 years (75%)</b> ]	4.5
5	<b>7 years (75%)</b> vs. [ $\frac{1}{2}$ , 15 years (75%); 5 years (75%)]	5.3
Indifference value	<b>6.5 years (75%)</b>	4.9

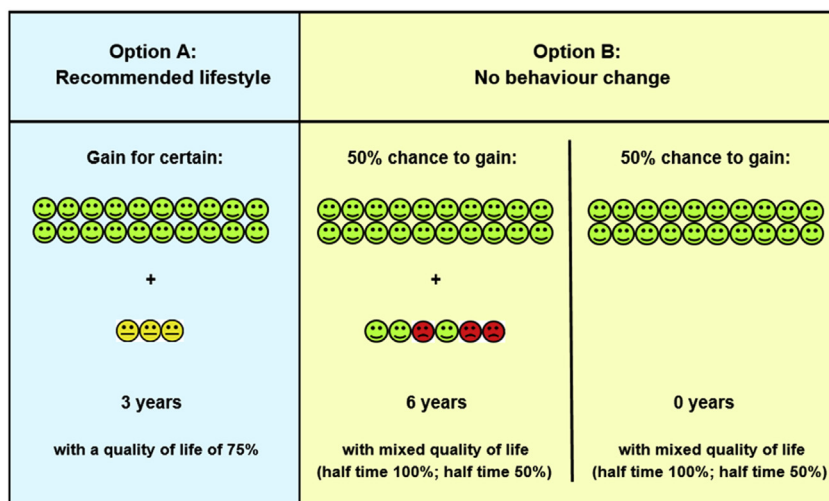


Fig. 1. Example of prospects displayed as smiley chains ( $j = 1$ ).

were made using Mann-Whitney U tests. In both cases, two-tailed p-values are reported.

### 3.4.2. Utility and loss aversion parameters

The five types of individual parameters were estimated through non-linear least squares regressions. For each participant, utility parameters (risk aversion coefficients and decision weights) were calculated, in both domains, to best fit the elicited data (i.e., the CEs) to the non-linear functions described in equations (7) and (9). In the gain [loss] domain, we estimated the values of  $\omega^+$  and  $\gamma$  [ $\omega^-$  and  $\delta$ ] that minimized the sum of squared residuals, i.e. the difference between the elicited data and the fitted value provided by the model ( $\omega^+$  and  $\omega^-$  were constrained between 0 and 1). After estimating the four utility parameters, we estimated the loss aversion coefficient based on equation (13). We also analysed the impact of observable characteristics by running ordinary least squares (OLS) regressions on each parameter estimate.

## 4. Results

### 4.1. Reliability

In order to check for answer consistency throughout the experiment, we repeated the first iteration, after the final iteration, for five different CEs. Overall, 110 individuals provided consistent answers for at least four out of five CEs (92%), indicating good reliability. In the T2DM group [control group], 39 participants (65%) provided consistent answers for the five CEs in both domains [49 participants (82%)], 13 participants (22%) for four out of five CEs [9 participants (15%)] and only 8 participants (13%) for three out of five CEs [2 participants

(3%)]. In both groups, no participants gave inconsistent answers for more than two out of five CEs. However, in order to minimise the bias due to unreliable answers, we decided to exclude participants who were not consistent for at least four out of five CEs. In the analysis, for subjects who answered inconsistently for one CE (e.g. they first expressed risk aversion for the CE, but then expressed risk seeking for the same CE when repeating the first iteration), we eliminated that CE and classified the subject according to their other answers. Therefore, the final sample sizes for analysis are 52 (T2DM group) and 58 (control group).

### 4.2. Characteristics of the participants

Table 4 presents a summary of the participants' characteristics in the final sample ( $n = 110$ ). Chi-square tests show no significant between-group differences in terms of gender ( $p = 0.14$ ), employment status ( $p = 0.23$ ), education level ( $p = 0.32$ ) or reliability ( $p = 0.14$ ). According to Mann-Whitney U tests, age difference was significant ( $p = 0.012$ ) but time to complete the questionnaire was not ( $p = 0.39$ ).

### 4.3. Utility for gains and losses

#### 4.3.1. CEs and risk attitudes

Table 5 classifies subjects according to their risk category in each domain. It shows that half of the subjects (49%; 30 in the T2DM group and 24 in the control group) were risk averse over the whole domain. The second largest group is made up of people who were risk averse in the gain domain and mixed in the loss domain (17% of the sample; 7 in the T2DM group and 12 in the control group). A large majority of subjects were classified into the risk aversion category for gains (70%),

Table 3  
Scenarios and associated QoL scores.

	Scenario 1 Behaviour change; No complication	Scenario 2 No behaviour change; No complication	Scenario 3 No behaviour change; Complication
Score	QoL: 75% (good)	QoL: 100% (perfect)	QoL: 50% (moderate)
Source (Mean [SD]) (Huang et al., 2007)	Utility attributed to 'conventional glucose control' (0.76 [0.31])	-	Utility attributed to 'lower extremity amputation' (0.55 [0.36])
Scenario description (Huang et al., 2007)	Constraints in daily life linked to precautionary behaviour: 'You will need to follow a diet, to exercise regularly, to see the doctor regularly, and to take daily medications.' 'For example, you may have to eat less of some foods you like, or experience mild to moderate side effects associated with your medications.'	No health-related constraints in everyday life	Constraints in daily life linked to a complication: 'You might experience mild to moderate pain, tiredness, or difficulties in performing daily tasks such as driving or cleaning the house.'

**Table 4**  
Characteristics of the participants.

		T2DM group	Control group	Total
Sample size		52	58	110
Gender	Male	32 (61.5%)	28 (48.3%)	60 (54.5%)
	Female	20 (38.5%)	30 (51.7%)	50 (45.5%)
Age	Median [IQ1-IQ3]	53.5 [46–57.75]	50 [36–56]	51.5 [40–57]
Employment	Employed (full time, part time)	39 (75%)	48 (82.8%)	87 (79.1%)
	Unemployed (looking for job, retired, disabled)	13 (25%)	10 (17.2%)	23 (20.9%)
Education	High school degree or no degree	20 (38.5%)	18 (31%)	38 (34.5%)
	Bachelor or graduate degree	32 (61.5%)	40 (69%)	72 (65.5%)
Reliability	5/5	37 (71.2%)	49 (84.5%)	86 (78.2%)
	4/5	15 (28.8%)	9 (15.5%)	24 (21.8%)
Duration (min)	Mean [SD]	21.5 [6.1]	20.9 [7.8]	21.2 [7.0]

**Table 5**  
Classification of subjects according to their risk category, for each domain.

	Losses				
	Risk averse	Risk neutral	Risk seeking	Mixed	Total
<b>T2DM group</b>					
Gains					
Risk averse	30	1	1	7	39
Risk neutral	0	0	0	0	0
Risk seeking	0	0	1	0	1
Mixed	3	0	4	5	12
Total	33	1	6	12	52
<b>Control group</b>					
Gains					
Risk averse	24	0	2	12	38
Risk neutral	0	0	0	0	0
Risk seeking	1	0	2	3	6
Mixed	3	1	1	9	14
Total	28	1	5	24	58

but only half of them for losses (55%). This difference in proportions is significant ( $p = 0.02$ ). Between-group comparisons do not show significant differences in terms of proportion of subjects classified into the risk averse and mixed categories with respect to gains (75% and 23% in the T2DM group vs 66% and 24% in the control group,  $p = 0.14$  and  $p = 0.90$ , respectively); however, there is a trend towards significant difference for risk seeking subjects (2% vs 10%,  $p = 0.07$ ). In the loss domain, results are more mixed but there are no significant differences in terms of proportions.

Table 6 reports the medians and interquartile ranges of individual CEs elicited in both groups. There is strong evidence for risk aversion, in both the gain and the loss domains. For four out of five CEs ( $j = \{2, 3, 4, 5\}$ ), risk aversion was higher in the gain domain. This difference is significant for  $j = \{4, 5\}$ . Conversely, for  $j = 1$ , risk aversion was significantly higher in the loss domain. Overall, 77% [7%, 16%] of the elicited CEs conveyed risk aversion [risk neutrality, risk seeking] for

**Table 6**  
Median CEs (absolute values) and Wilcoxon tests on the difference between gains and losses.

CEs	T2DM group			Control group			Total			
	Gains	Losses	p-value	Gains	Losses	p-value	Gains	Losses	p-value	
j = 1	Median (IQ1-IQ3)	2.50 (0.63–3.00)	0.75 (0.25–2.75)	< 0.001***	2.50 (0.50–3.31)	2.00 (0.25–3.32)	0.06*	2.50 (0.50–3.06)	1.25 (0.25–3.00)	< 0.001***
j = 2	Median (IQ1-IQ3)	3.00 (1.25–4.50)	3.50 (0.63–5.00)	0.45	4.00 (2.00–5.00)	4.50 (2.44–5.50)	0.26	3.50 (2.00–4.50)	4.50 (2.00–5.50)	0.17
j = 3	Median (IQ1-IQ3)	3.00 (1.75–5.50)	3.00 (1.00–6.00)	0.85	4.00 (1.25–6.00)	5.25 (3.00–6.00)	0.86	4.00 (1.25–6.00)	4.50 (1.13–6.00)	0.96
j = 4	Median (IQ1-IQ3)	5.25 (5.00–8.25)	8.75 (5.00–10.00)	0.026**	7.00 (5.00–9.00)	8.75 (6.31–10.00)	0.009***	6.50 (5.00–9.00)	8.75 (5.00–10.00)	< 0.001***
j = 5	Median (IQ1-IQ3)	9.00 (9.00–10.00)	10.50 (9.00–12.38)	< 0.001***	10.00 (9.00–12.00)	12.00 (9.00–12.13)	0.02**	9.00 (9.00–12.00)	11.25 (9.00–12.13)	< 0.001***

gains, whereas 65% [15%, 20%] conveyed risk aversion [risk neutrality, risk seeking] for losses. Median CEs elicited in the control group were often higher than and always at least as high as those elicited in the T2DM group, indicating higher risk aversion in the T2DM group. Differences are significant for one CE in the gain domain ( $j = 5$ ;  $p$ -value < 0.01) and two CEs in the loss domain ( $j = 2$ ;  $p$ -value = 0.034;  $j = 5$ ;  $p$ -value = 0.093).

4.3.2. Utility parameters

Table 7 reports the median utility parameters, based on the individual data. The median coefficients were significantly different from 0 for gains ( $\gamma = 3.46$ ,  $p < 0.01$ ) and losses ( $\delta = 1.91$ ,  $p < 0.01$ ), but were not significantly different from each other ( $p = 0.84$ ). The distributions of individual utility parameters are provided in Appendix B - Fig. 1. Probability weighting was significant in the gain domain ( $\omega^+ = 0.49$ ;  $p < 0.01$ ).

Overall, a large majority of subjects had concave utility functions in both domains (see Table 8). In the T2DM group, in particular, only 11 subjects (21%) had a convex utility in one of the two domains.

4.4. Loss aversion

We observed a high degree of risk aversion in the mixed prospect, with 86% of the responses being risk averse. Only 11 [5] individuals (10% [5%]) were risk seeking [risk neutral]. The median coefficient for loss aversion is significantly different from 1 ( $\lambda = 1.19$ ;  $p < 0.01$ ; see Table 7). Appendix B - Fig. 2 shows the distribution of individual coefficients for loss aversion.

4.5. Risk attitudes and observable characteristics

Table 9 shows the results of OLS regressions performed on each of the five parameters of interest. We studied the impact of five variables: 1) gender; 2) age (see Appendix D for more details on the age distribution); 3) T2DM status; 4) education; and 5) employment.

**Table 7**  
Estimation results for the parameters of interest.

		$\gamma$	$\omega^+$	$\delta$	$\omega^-$	$\lambda$
T2DM group (n = 52)	Median (IQ1-IQ3)	3.81 (1.45–9.94)	0.49 (0.48–0.50)	2.83 (0.77–8.14)	0.50 (0.49–0.50)	1.19 (0.91–2.43)
Control group (n = 58)	Median (IQ1-IQ3)	2.86 (0.47–6.86)	0.50 (0.49–0.50)	1.29 (–0.07–3.69)	0.50 (0.49–0.51)	1.19 (0.56–1.92)
Total (n = 110)	Median (IQ1-IQ3)	3.46 (1.03–8.91)	0.49 (0.48–0.50)	1.91 (0.36–5.23)	0.50 (0.49–0.50)	1.19 (0.62–2.00)

Note 1: In the gain domain,  $u(x)$  concave [linear, convex] if  $x > 0$  [ $x = 0$ ,  $x < 0$ ]. In the loss domain,  $u(x)$  concave [linear, convex] if  $x < 0$  [ $x = 0$ ,  $x > 0$ ].

Note 2: Loss aversion [neutral, seeking] when  $\lambda > 1$  [ $\lambda = 1$ ,  $\lambda < 1$ ].

Note 3: All coefficients were significantly ( $p < 0.01$ ) different from 0 ( $\gamma$  and  $\delta$ ), 0.5 ( $\omega^+$  and  $\omega^-$ ), and 1 ( $\lambda$ ).

**Table 8**  
Classification of subjects according to their utility functions.

	Losses		Total
	Concave	Convex	
<b>T2DM group</b>			
Gains			
Concave	43	6	49
Convex	1	2	3
Total	44	8	52
<b>Control group</b>			
Gains			
Concave	38	8	46
Convex	5	7	12
Total	43	15	58

Firstly, we observed a clear age effect on risk aversion coefficients. The older the individual, the higher the risk aversion coefficient for both the gain ( $p < 0.01$  for both group categories) and the loss domain ( $p = 0.06$  for the senior group effect and  $p = 0.01$  for the veteran group effect). Secondly, people with T2DM were characterized by stronger probability underweighting in the gain domain, which suggests higher risk aversion than controls, on average, in this domain ( $p = 0.01$ ). Thirdly, significant interactions between education level and employment status suggest the presence of underlying subgroup effects. In

**Table 9**  
Ordinary least square regressions on the parameter estimates.

	Dependent variable				
	$\gamma$	$\omega^+$	$\delta$	$\omega^-$	$\lambda$
<b>Gender</b>					
Male (reference)	–	–	–	–	–
Female	2.683 (3.029)	–0.003 (0.010)	0.951 (3.126)	< 0.001 (0.004)	0.948 (0.916)
<b>Age</b>					
Junior (reference)	–	–	–	–	–
Senior	9.330*** (3.368)	–0.012 (0.010)	7.303* (3.822)	0.003 (0.005)	–0.022 (0.534)
Veteran	11.327*** (3.719)	–0.022 (0.016)	12.258** (4.673)	–0.003 (0.005)	1.507 (1.379)
<b>Group</b>					
T2DM (reference)	–	–	–	–	–
Control	–1.196 (2.935)	0.027** (0.010)	–3.070 (3.240)	< 0.001 (0.004)	1.103 (1.577)
<b>Employment</b>					
Not employed (reference)	–	–	–	–	–
Employed	2.699 (5.419)	–0.013 (0.033)	4.568 (7.929)	< 0.001 (0.008)	–0.152 (0.603)
<b>Education</b>					
High school degree or no degree (reference)	–	–	–	–	–
Bachelor or graduate degree	–10.821* (6.286)	0.034 (0.030)	–11.782 (7.828)	0.007 (0.009)	4.619 (4.841)
<b>Employment*Education</b>					
Not employed/High school degree or no degree (reference)	–	–	–	–	–
Employed/Bachelor or graduate degree	13.240* (7.453)	–0.032 (0.034)	15.031 (9.249)	–0.005 (0.010)	–4.440 (4.586)
Constant	–2.173 (4.348)	0.477*** (0.016)	2.165 (5.050)	0.495*** (0.006)	0.055 (1.837)
Observations	110	110	110	110	110
R <sup>2</sup>	0.107	0.113	0.097	0.028	0.084
Prob > F	0.031	0.321	0.090	0.892	0.909

Note 1: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

Note 2: Gender categories (male = 0; female = 1); age categories: junior (30–45 years old) = 0; senior (46–55 years old) = 1; veteran (56–60 years old) = 2; group categories (T2DM = 0; control = 1); education categories (high school degree or no degree = 0; bachelor or graduate degree = 1); employment categories (not employed = 0; employed = 1).

order to further investigate the effects of age and T2DM status on risk aversion, we performed additional OLS regressions to check whether these results held when including only participants in the sample who provided fully consistent answers (i.e. excluding people who provided one inconsistent answer). Results displayed in [Appendix E](#) confirmed the existence of both effects.

## 5. Discussion

### 5.1. Novelty

Our study extends previous research on decision-making under health risks in two ways. First, we expand on previous work investigating risk attitudes and PT utility in the health domain by building the prospects upon more realistic scenarios (decision on whether or not to adopt self-management behaviour faced by people living with a manageable chronic disease) and using health outcomes that include both dimensions of health utility: life duration and QoL. Second, while previous studies used a student or general population, our study population was selected to allow comparisons between people living with a manageable chronic disease (i.e. patients actually facing such risky choices) and people without chronic disease. These aspects are crucial in the perspective of bridging theoretical results and actual policy-making. A key research axis of behavioural economics,

which is of primary interest here, is to find ways of targeting identified decision-making biases to nudge people towards a given (recommended) behaviour. By targeting the biases identified in this study, more effective interventions to encourage adherence to self-care behaviours in patient populations with manageable chronic disease may be developed (see 5.4 for more details).

## 5.2. Risk attitudes

Our results show that participants expressed a high degree of risk aversion, both in the gain and in the loss domains, and significant loss aversion. Two phenomena seem to explain this trend. Firstly, participants had very concave utility functions, which translated into high utility parameters for both gains and losses. This is in line with previous studies conducted on student (Attema et al., 2013) and general populations (Attema et al., 2016) and suggests that the role of the RP is less crucial for health than for money. Another possibility is that, despite making the RP as salient as possible in the instructions (use of visual aids), people's own idea of how long they may live was still stronger than the induced time horizon. More research that explicitly investigates this point is needed. Secondly, risk aversion was also reflected in probability underweighting of probability 0.5 (only significant in the gain domain). Similar effects were reported in the abovementioned studies. Regarding loss aversion, our coefficient is comparable with those reported in the literature for the health domain (Attema et al., 2013).

However, a feature specifically related to the study of risk attitude for life years is that life years by definition involve a time component. Consequently, the results will be affected by time preferences. In fact, the utility function for life duration can be regarded as reflecting both diminishing returns to lifetime and discounting of future life years, and it is hard to disentangle these effects. The incorporation of losses in this domain is particularly challenging, because only outcomes involving future (as opposed to past) lifetime are useful and, therefore, the RP has to be in the future in order to allow for losses. This creates two problems. First, because the changes in health occur at some point in the future, the observed choices may have been different if the changes had taken effect immediately. Second, the higher the loss, the closer one gets to the present, so that as the individual moves farther away from their RP, the influence of time preferences is reduced. As a result, the concavity resulting from positive time preference will neutralize any convexity inherent to losses, whereas there is no such influence of time preference for monetary outcomes. This may explain why we find concave utility for losses on balance.

We have also performed robustness analyses to test for any effect caused by the onset of the health changes being only in 15 years for gains. Table 1 in Appendix C shows the results, indicating no large differences when allowing for discounting these 15 years. As a result, one could argue that the S-shaped utility function typically found for money does not apply to health, where the distinction between gains and losses appears less influential. This does not detract from the robust evidence of loss aversion found for health outcomes. Hence, the framing of a question as a choice between the status quo and a mixed prospect clearly induces more risk aversion than framing questions as choices between two gain prospects or two loss prospects, even when the distinction between gains and losses appears less natural as in the case of life duration. Table 2 in Appendix C illustrates this in more detail, where the results of an additional analysis are presented that combines the CEs of both the gain and the loss prospects to elicit one single utility parameter and one single decision weight, while still using the results of the mixed prospect to estimate loss aversion.

Moreover, two interesting subgroup effects have been observed in this study. Firstly, age was negatively related to risk attitudes. Splitting our sample into three groups of equivalent size, as a compromise between tractability (i.e. benefiting from sufficient variability in the data) and accuracy, significant effects were found on utility parameters for

gains and losses. Such effects have already been reported in the health domain: Dohmen et al. (2011) showed that older individuals express, on average, higher risk aversion than younger individuals and Rolison et al. (2013) found that health risk-taking reduces smoothly with age. We examined a specific trade-off, in which choices were likely to be influenced by age. The median age of the sample, combined with the RP of living 20 more years, means that most subjects were asked to contemplate their life at (at least) age 70 and make decisions accordingly. From this perspective, it is likely that the QoL dimension had more weight than the life duration dimension in the decision-making process. For an older subject, the prospect of living the last years of his/her life with a constant, relatively good QoL (75%) was likely to be enough to offset the chance of living longer, i.e. the best outcome of the risky option. Conversely, following the same reasoning, the QoL dimension was less likely to prevail over the life duration dimension in decisions made by younger subjects. Hence, younger subjects seem to care relatively less about quality of life than older subjects, stressing the importance of implementing age-specific health promotion policies.

Secondly, we found that people with T2DM were, on average, underweighting probability 0.5 more strongly than controls, suggesting higher risk aversion in the T2DM group. However, caution is required about the interpretation of this effect, as it was no longer significant when including only fully consistent subjects. Rather than revealing different underlying risk preferences between patients and controls, a possible, alternative explanation is that the elicitation method could have enhanced the observed T2DM effect. Indeed, the higher degree of risk aversion found with T2DM patients could be interpreted as a difference in terms of perception of the task, and more specifically as an adjustment of their RP during the experiment. Since people with T2DM had already 'integrated' the cost of behaviour change (they had already had to change their behaviour), and although they were explicitly told to forget about their condition and imagine living with perfect QoL at the beginning of tasks 1 and 2, they could have implicitly taken 75% of QoL, i.e. the QoL of the safe option, as their RP (as opposed to controls, who took 100% of QoL as their RP). It is assumed that each individual adjusts, to a certain extent, the RP according to her own situation, experience or perceptions; setting up a common RP allows to highlight these differences. In that case, gain and loss prospects were possibly interpreted as mixed prospects by some participants in the T2DM group. Option A was seen as the status quo, and option B was seen as a mixed prospect offering the chance to 'gain' or 'lose' 25% of QoL. As a consequence, because of loss aversion, this could have led to a higher degree of risk aversion in the T2DM group. Future research could try to avoid these problems; e.g. by eliciting respondents' reference points before starting the main experiment and subsequently using these individual-specific RP to elicit risk preferences.

## 5.3. Strengths and limitations

The data in this study were collected following procedures intended to ensure high quality. Firstly, the questionnaire was developed in collaboration with both health professionals and patients in order to be as user-friendly as possible. We used visual aids that facilitated participants' understanding. Secondly, the experimenter running the interview was continually present as a support for the participant, throughout the questionnaire. He made sure that both the instructions and the questions were well understood. This was a key aspect of the procedure: no participant was asked to read the instructions or answer the questions on their own. The written instructions were accompanied by clear, additional verbal explanations. This translated into a large majority of participants providing consistent answers for at least four out of five CEs (92%). Despite a higher degree of complexity in the design of the prospects, the reliability of our procedure compares to those of earlier studies (Attema et al., 2013; Abdellaoui et al., 2008; Stott, 2006).

On the other hand, the sample size is small, which limits the data



analysis. Because T2DM usually arises in the early 60s, a major difficulty of the study was to recruit patients with T2DM aged 60 or less, and even more challenging, aged 50 or less. This constraint should be taken into account when looking at the final sample size of the T2DM group ( $n = 52$ ). We tried to ensure that controls were matched by age, while also trying to minimise the risk of selection bias by recruiting these participants randomly at the same surgery practice. Statistical tests showed no between-group differences in terms of gender, employment status, education level, or answer reliability. Only a slight difference in terms of age (the median age of the T2DM group was higher) was found after exclusion of individuals who provided more than one inconsistent answer. Individuals who were not fully consistent in their answers ( $n = 30$ ) turned out to be heterogeneous in terms of demographic and socio-economic characteristics, which minimizes the risk of selection bias and supports our elicitation procedure. However, significantly more individuals from the T2DM group had to be excluded from the analysis than from the control group (8 participants vs 2 participants). Although caution is required in the interpretation of this difference, it may be explained by underlying differences in terms of cognitive abilities between people with T2DM and controls. Recent studies have shown that diabetes impose a chronic negative effect on cognitive and decision-making skills (Chung et al., 2015; Hazari et al., 2015; Rawlings et al., 2014). This should be borne in mind when designing future studies involving cognitive tasks with T2DM populations.

Last, it is important to bear in mind other limitations inherent in the elicitation method. Firstly, we designed the prospects using a broad notion of health-related QoL, selecting three scores supposed to characterise three QoL states. These scores were the result of a trade-off between four criteria, including ease of understanding and realism. Despite our efforts to minimise rating biases, we could not completely rule out individual variations in the way these scores were perceived. For example, a QoL score of 100% is likely to be perceived differently according to whether a person is 30 or 60 years old. One way of dealing with this issue would be to elicit each individual's own QoL score before running the experiment, and then use these personalised scores in the prospects. Such an approach would, however, increase both the length and the complexity of the experiment. Secondly, using only one single probability ( $p = 0.5$ ) in the prospects prevents conclusions from being drawn about the decision weights attached to other probabilities. In particular, the tendency of people to overweight low probabilities and underweight high probabilities has been well-described in the literature (Gonzalez and Wu, 1999). Thirdly, since separating the two attributes (quality of life and life duration) and assessing their separate utility functions would have caused a substantially higher response burden, we analysed utilities of QALYs. That is, we assumed that the risk attitude for quality of life was not systematically different from the risk attitude for life years. This is in contrast to the findings of van der Pol and Ruggeri (2008), who reported risk seeking for quality of life alongside risk aversion for life years. However, the evidence with respect to risk attitudes regarding life years and quality of life is mixed, with other evidence suggesting risk aversion over quality of life (Attema et al., 2016). Furthermore, we expressed quality of life in percentages whereas van der Pol and Ruggeri (2008) used EQ-5D classifications, and our gambles did not include immediate death as opposed to the lifetime gambles of van der Pol and Ruggeri (2008). It is therefore not clear that their results also apply to our setting.

#### 5.4. Recommendations

In the health domain, risky decisions made by people living with a chronic disease may greatly impact their life expectancy and QoL. Evidence of risk aversion found in this study suggests that risk seeking behaviour may not explain lack of adherence to self-management observed in T2DM populations. Although there is no data allowing us to link the risk attitudes measured in this study with objective measures of patients' self-management, participants preferred choosing the safer

option when facing scenarios that depict the risks inherent to each behavioural option. In other words, when they can clearly visualize (and thus be fully aware of) the risk associated with non-adherence, people seem averse to it and prefer adhering to self-management. These results suggest that in real life non-adherence to self-management may be explained, at least partly, by an underestimation of the risks associated with risky behaviour. In the medical literature, it has been shown that T2DM patients largely underestimate the risks of diabetes-related complications (Rouyard et al., 2017). One may argue that, regardless of their level of risk perceptions, if these patients are risk seeking towards behavioural choices associated with the management of their condition, higher risk perceptions would not increase adherence to self-management. Our study shows that this is not the case, i.e. that if patients had a higher awareness of the risks associated with non-adherence to self-management, they may change their behaviour. This does not necessarily contradict Simon-Tuval et al. (2016) who found an association between risk-seeking behaviour for money and non-adherence to T2DM self-management behaviour. Putting aside the differences between utility for money and utility for health, it is possible that risk seeking patients (both towards money and health) are also among the ones who are the least adherent to self-management. However, our study shows that this behaviour is uncommon when risky choices are specific to T2DM self-management and hence may not be relevant to explain the high rates of non-adherence observed in practice. Further research to link elicited risk preferences for health outcomes with objective measures of adherence to self-management behaviour would be interesting.

A direct implication of our findings is that they support the design of interventions that raise awareness of diabetes-related health risks and take advantage of people's loss aversion. New risk communication strategies that make the risk look more concrete and proximal are a good example of how these two levers for action could be pulled. For example, Spiegelhalter (2012) suggests providing patients with estimates of how much lifetime they lose when they engage in risky behaviours. The concept of "microlife", which represents half an hour of adult life expectancy, was created to better communicate losses or gains of lifetime associated with risky health behaviours (e.g. "a lifetime habit of an extra portion of red meat per day is associated with a loss of 1 microlife per day"). This tool also presents the advantage of pulling the present bias lever (Mørkbak et al., 2017), as higher or lower levels of risk can be interpreted as "ageing faster or slower than an average person". Recently, a pilot randomised controlled trial was conducted in primary care to assess the feasibility of using such new risk communication strategies with poorly controlled people with T2DM (Rouyard et al., 2018). The objective of the intervention was to nudge this patient population towards better adherence to self-management by targeting some of the factors underlying such behaviour, including risk and loss aversion. Personalised risk information was calculated based on a validated prognostic model and delivered to patients in an innovative way. Traditional probabilistic risk information was converted into metrics and formats more easily grasped by patients, including patients' 'effective heart age' (Lopez-Gonzalez et al., 2015) instead of the more abstract probability of experiencing a heart attack (pulling the risk aversion lever) and daily losses of life time associated with lack of adherence to self-care behaviours (pulling the loss aversion lever). Recall of risk information after 3 months and intentions to change diet were significantly improved in the intervention group. This is a concrete example of how such information can be used, in practice and in combination with other strategies, to increase adherence to self-care behaviours in this particularly difficult patient population.

Finally, the age-related difference in risk attitudes found in this study suggests that a different approach is needed for younger T2DM patients. Because of lower risk aversion, such interventions are likely to be less effective in this population. Efforts to develop alternative strategies should be of high priority, as worrying differences between younger and older T2DM patients have been shown in terms of glycaemic control (Selvin and Parrinello, 2013) and onset of complications

(Al Saeed et al., 2016; Copeland et al., 2013). This is partly due to lower adherence to self-management (Villarroel et al., 2015) (that may be caused by lower risk aversion and present preferences) and partly due to younger-onset T2DM which is more aggressive by nature and thus more challenging to control (Al Saeed et al., 2016; Copeland et al., 2013).

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.socscimed.2018.08.007>

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