Perception of Own Death Risk

A Reassessment of Road-Traffic Mortality Risk

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October 7, 2008

Abstract This study examines individuals' perception of their own road-mortality risk. Swedish data on respondents' subjective risk beliefs is used and compared with objective risk estimates. The objective risk is defined as the risk of the respondent's own age and gender group, and it is found that low and high risk groups over- and underassess their risk levels, respectively. This study replicates the analysis used by Andersson and Lundborg (2007) and the pattern of over- and underassessment found confirms their findings. As in their study, risk beliefs are updated in line with the Bayesian learning model, a relationship not statistically significant in this study, though. Regarding results of individual characteristics and risk beliefs in both studies, whereas, e.g., gender effects are robust, other results suggest a weak relationship between the perception of own road-mortality risk and individual characteristics.

Key words Bayesian learning, Overall risk, Peers, Road-traffic risk

JEL codes: C21, D81, D83, I18

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[⋆⋆] Financial support from VTI, VINNOVA, the Centre for Transport Studies, Stockholm, and La Fondation Jean-Jacques Laffont is gratefully acknowledged. The usual disclaimers apply.

1 Introduction

Individuals engage in risky activities on a daily basis, some of which they do voluntarily, like smoking or skiing, where for the latter the risk is part of the benefit of the activity. Other hazards are part of daily routines that cannot easily be avoided, e.g. eating or commuting to work or school. If individuals have accurate perceptions about risks, they will be able to make well-informed decisions and expose themselves to an optimal risk level.

Numerous studies have examined individuals' perception of mortality risk (Slovic, 2000), and the empirical evidence suggests that individuals misperceive mortality risks. This bias does not only influence individuals' ability to make well-informed decisions, it may also result in policy makers not allocating resources in an optimal manner, since they may base their decisions on objective risk measures or experts' assessments. Biased risk perception may also have an impact on preference elicitation. For instance, if individuals overassess mortality risks, monetary estimates of reducing mortality risks may be positively biased (Gayer et al., 2000; Bleichrodt and Eeckhoudt, 2006). Hence, knowledge about individual risk perception is important not only from a research perspective, but also from a policy perspective.

Most studies of risk beliefs examine how individuals perceive the risk of different hazardous activities for a given population (e.g. Hakes and Viscusi, 1997, 2004), and the evidence from them strongly suggests that individuals over- and underassess the probability of low and high risk events, respectively (Lichtenstein et al., 1978; Morgan and et al., 1983; Benjamin and Dougan, 1997; Viscusi et al., 1997; Hakes and Viscusi, 2004; Armantier, 2006). Andersson and Lundborg (2007) extended the analysis of mortality risk perception and instead examined how individuals perceive mortality risks to themselves. They studied two risks, road-traffic and overall mortality risk, and found a similar pattern to the one in the literature on population risks for road-traffic mortality, i.e. an over- and underassessment for low and high risk groups, respectively. For overall mortality risk they found that all groups underassessed the risk.

This study further examines individuals' perception of their own mortality risk. We use a data set from a Swedish contingent valuation (CVM) study in which respondents were asked about their preferences for increased food and car safety. This data set provides us with individual-level data, which enables us to examine how individual risk perception and bias are affected by socio-economic and demographic factors. Hakes and Viscusi (2004) and Andersson and Lundborg (2007) used individual-level data in their analyses of perceived mortality risk and found that several socio-economic and demographic attributes, for instance education, income, health status and gender, influenced individuals' risk perception.

The aims of this study are the same as in Andersson and Lundborg (2007), i.e. to examine if: (i) perceived risks differ from objective risks, (ii) the probability of underestimation varies in terms of demographic characteristics, (iii) there is any correlation between the magnitude of bias and individual characteristics, and (iv) the risk perception formation of own risk follows the pattern found in Lichtenstein et al. (1978). As in Andersson and Lundborg (2007), objective risk is defined as the risk of the respondents' peers (i.e. their own gender and age group). By conducting a similar analysis we are able to examine whether the findings in Andersson and Lundborg (2007) are robust, which is one objective of this study.

The following section briefly reports on previous findings in the empirical literature on mortality risk perception, and describes the *Bayesian learning model*. We thereafter describe the data set used. Section 4 contains the results. We find that low risk groups overassess their mortality risk, whereas high risk groups underassess their risk. Regarding the size of the risk bias, we only find statistically significant correlations between individual attributes and the size of the bias for respondents who perceive their risk to be lower than that of their peers. Moreover, we find weak support for a Bayesian updating of individuals' risk perception. We discuss and relate our results to Andersson and Lundborg (2007) in section 5, before concluding the study in section 6.

2 Risk perception

2.1 Empirical findings

It is well established that lay people's subjective risk beliefs differ from objective risk measure (Sunstein, 2002; Slimak and Dietz, 2006). Reasons for this difference are individuals' known difficulties of judging small probabilities (Kahneman and Tversky, 1979; Kahneman et al., 1982), and that lay people are more influenced in their perceptions by media coverage, own experience, etc., of the hazards (Slovic, 1987).

The empirical evidence also suggests that individual characteristics influence risk beliefs, and one characteristic that has been thoroughly examined is gender. There is strong evidence that females perceive risky activities as more dangerous than males do (Viscusi, 1991; Savage, 1993; Liu and Hsieh, 1995; Davidson and Freudenberg, 1996; Antoñanzas et al., 2000; Dosman et al., 2001; Brown and Cotton, 2003; Lundborg and Lindgren, 2004). The reason for this gender difference has been debated, and suggestions that the difference is biological, or that women are less informed than men, have been questioned (Flynn et al., 1994; Finucane et al., 2000; Barke et al., 1997; Slovic et al., 1997; Steger and Witt, 1989). Plausible explanations are rather that women dislike risk more than men (Powell and Ansic, 1997; Jianakoplos and Bernasek, 1998; Hersch, 1998) and that men often have more go gain from risky activities (Davidson and Freudenberg, 1996).

Other attributes that have been shown to influence risk perception are age, income level, and education. Whereas the effect of age varies with the type of hazard (Dosman et al., 2001; Dickie and Gerking, 1996), income and education level seem to reduce the individual perception of risk (Savage, 1993; Dosman et al., 2001). There is also evidence suggesting that the more educated have a more accurate risk perception (Hakes and Viscusi, 2004). Further, it has also been found that the presence of children in the household (Dosman et al., 2001; Davidson and Freudenberg, 1996) and negative experience of the hazardous activity (Dickie and Gerking, 1996; Matthews and Moran, 1986) increase the risk perception.

This study examines individuals' perception of their own traffic-mortality risk. The empirical evidence would suggest that individuals will underassess this risk for two reasons: (i) exposure to the risk is to some degree voluntary, which means that it is less "troublesome" compared to other risks (Sunstein, 2002, p. 67), and (ii) optimism bias is known to be greater for risks to oneself and risks that are perceived controllable by one's own actions (Weinstein, 1989). Based on other empirical evidence, we also expect the optimism bias to be larger for men than for women (DeJoy, 1992), and larger for younger than for older male drivers (Matthews and Moran, 1986; Glendon et al., 1996).

The results in Andersson and Lundborg (2007) did not support a systematic optimism bias, the sign and size of the bias depended on gender and age. The empirical evidence on risk perception and traffic risk suggests a dependence on age and gender, with females and older respondents having a higher perception of risk (Rafaely et al., 2008; Rosenblom et al., 2008). Research also suggests that individuals' perception of the risk of their own age group is more accurate that their perception of population risks or the risk of other groups (Benjamin and Dougan, 1997; Benjamin et al., 2001; Armantier, 2006; Rafaely et al., 2008). Hence, based on the empirical evidence, we expect females to be more likely to overassess their risk, whereas the optimism bias is likely to be the largest for young males.

2.2 Bayesian risk formation

Numerous studies have found evidence suggesting that individuals update their risk perception in a Bayesian manner (Viscusi, 1985; Smith and Johnson, 1988; Viscusi, 1991, 1992; Dickie and Gerking, 1996; Hakes and Viscusi, 1997; Gayer et al., 2000). The Bayesian learning model is outlined in several other papers (e.g. Viscusi, 1989, 1998) and for reasons of brevity the description of the model is kept short here.

The basic concept of the Bayesian updating process is illustrated in Figure 1. Individuals' prior risk beliefs are represented by the horizontal line. When they obtain new information, for instance through campaigns or their own experience, they update their beliefs. If the new information resulted in perfectly informed individuals, the perceived risk would be represented by the 45 degree line. However, empirical evidence suggests that learning is only partial, and, hence, individuals overassess and underassess low and high probability events, respectively, as represented by the unbroken line (Lichtenstein et al., 1978; Hakes and Viscusi, 2004; Armantier, 2006).

[Figure 1 about here.]

New risk information may take different forms. We follow Viscusi (1991) and assume that the individuals' risk beliefs are determined by three sources of information; prior risk assessment (q), experience (a), and "specific risk information" (r). Experience refers not only to experience of risky activities, but also to demographic and socio-economic characteristics that can be assumed to influence the individual's experience of the risks, e.g. gender or wealth level. Specific risk information refers to information about risks that the individual is exposed to, e.g. campaigns about the risk of smoking, media coverage of earth quakes, or information on safety rankings of cars.

Based on the information sources above, the individual's risk beliefs may be defined as a weighted average of these sources,

$$p = \frac{\lambda_1 q + \lambda_2 a + \lambda_3 r}{\lambda_1 + \lambda_2 + \lambda_3}, \tag{1}$$

where λ_1, λ_2,and λ_3 denote the information content associated with q, a, and r, respectively. Let $\theta_i = \lambda_i/(\lambda_1 + \lambda_2 + \lambda_3),\ i \in \{1, 2, 3\}$, then Eq. 1 may be written as,

$$p = \theta_1 q + \theta_2 a + \theta_3 r. \tag{2}$$

Equation 1 may be used to predict how new and/or changes in information content affect individual risk perception. For instance, by differentiating Eq. (1) with respect to λ_3 we can predict how a change in the informational content associated with risk information affects the individual's risk perception,

$$\frac{\partial p}{\partial \lambda_3} = \frac{\lambda_1(r - q) + \lambda_2(r - a)}{(\lambda_1 + \lambda_2 + \lambda_3)^2}, \tag{3}$$

and, thus,

$$\frac{\partial p}{\partial \lambda_3} > 0 \text{ if } r > \frac{\lambda_1 q + \lambda_2 a}{\lambda_1 + \lambda_2}. \tag{4}$$

Equation (4) predicts that if the individual's experience of the risk and prior beliefs are lower than the specific risk information, then the perceived risk will increase as a result of the individual assigning more weight to the risk information.

3 Data

The data originate from a contingent valuation (CVM) survey conducted in Sweden in the fall of 2006. The aim of the survey was to elicit respondents' preferences for food and car safety, i.e. their willingness to pay (WTP) to reduce the risk of these activities. This study only analyzes the information from the survey on the respondents' risk perception.[1]

[1] The respondents' preferences for food and car safety are analyzed in Sundström et al. (2008) and Andersson et al. (2008), respectively.

The CVM survey was distributed to 1,898 randomly chosen individuals as a postal questionnaire. A total of 34 surveys could not be delivered because of "recipient unknown" (e.g. the respondents had moved or the address was incorrect), and after two reminders a 49.4 percent response rate was achieved, i.e. $n = 920$. The respondents received a paper copy of the questionnaire, but were also informed in the accompanying covering letter that they had the option to complete the questionnaire on the web. Only 49 respondents chose that option, and thus, with few exceptions, observations were from respondents answering the paper questionnaire.[2]

The questionnaire consisted of five sections. The first section contained questions mainly related to food safety with a focus on risk perception, handling, experience, etc. In the second section the respondents faced an evaluation example. The aim of this section was to train respondents in trading wealth for safety. In order to communicate the risk and to help respondents understand the magnitude of the risk, a visual aid, in the form of a grid consisting of 10,000 white squares with the risks visualized as black squares, was included in this section (Corso et al., 2001). The third section contained the WTP question for food safety, and again the same visual aid was used to communicate the baseline and the change of the risk levels. The fifth and final section asked follow-up questions on demographics and socio-economics.

The fourth section of the questionnaire focused on car safety and the question about individual risk perception used in this study was asked in that section. In order to test for framing effects on respondents' WTP, two versions of the questionnaire were constructed; one subsample with a monthly scenario, and the other subsample with an annual scenario. Thus, baseline risks, risk reductions, and payments were adapted to the time frame given. For this study the answers to the monthly scenario have been converted to annual values.

At the beginning of the section on car safety, the respondents were informed that (freely translated from Swedish):

> *The annual average risk of a fatal car crash is 7 in 100,000. The risk, though, is not only related to the characteristics of the car itself, and we would, therefore, like to ask some questions about your background as a driver/passenger.*

The objective risk was estimated as the ratio between the number of annual fatalities in cars in relation to the number of cars in use. This risk measure has been used in hedonic price-risk studies in the car market (Atkinson and Halvorsen, 1990; Dreyfus and Viscusi, 1995; Andersson, 2005) and is not a probability measure but a risk ratio (the risk measure could be larger than one). It is close to the population road-mortality risk, 6.42 per 100,000 (see Table 2), and has the advantage for the WTP question that the

[2] For a fuller description of the survey and the subgroups, see Sundström et al. (2008).

baseline risk is higher compared with a measure based on car fatalities in relation to the population. This means that the risk reductions the respondents were asked to state their WTP for may be larger and, thus, easier to communicate. Hence, we use the respondents' answers about car-mortality risk as a proxy for road-mortality risk, and from now on subjective risk in this study is defined as population road-mortality risk.

After being presented with the information above, the respondents were then asked questions about whether they had a driving licence, access to a car in the household, driving or travelling distance by car and traffic injury experience, before they were asked about their own perceived mortality risk. This question was framed as follows:

If the annual average risk of dying as a result of a car crash is 7 in 100,000, what do you think is your own annual risk of dying as a result of a car crash?

I think that the risk is ...... in 100,000.

As explained above, to improve respondents' understanding of the probability levels, the visual aids were used twice in the survey. Since the visual aids had been presented twice to the respondents before the WTP scenario on car safety, it was decided that it was not necessary to include the grid in that section as well.

4 Results

4.1 Descriptive statistics

The descriptive statistics of the survey are shown in Table 1. The last column shows mean values of the general Swedish population of the relevant age group (18-74) for variables chosen to examine the representativeness of the sample. Besides the proportion of female respondents, which is higher compared with the general population, 59.6 vs. 49.6 percent, our sample appears to be representative of the general Swedish population. The high share of female respondents is assumed to be a result of the fact that the first half of the survey concerned food safety. Swedish women are still responsible for most of the household food production (> 60%) (Rydenstam, 2008), and may therefore have a higher interest in food safey. Self-reported health status was obtained by asking respondents to mark their perceived health status on a visual analog scale in the form of a thermometer ranging from 0 to 100, where 100 was the best imaginable health state (EuroQol Group, 1990).

[Table 1 about here.]

Objective and perceived risks for age groups and gender are shown in Table 2. Objective risks are based on the number of fatalities over 8 years, i.e. 1999-2006. Per 100,000, the overall mortality risk is 6.42, and 2.96 and 9.86 for women and men, respectively. Table 2 also reveals that men have a higher mortality risk for all age groups, and that the mortality risk follows a U-shape over the life cycle. That men are more likely to die in road traffic and that the objective mortality risk is U-shaped over age are not unique for Sweden (Elvik and Vaa, 2004).[3] From an international perspective, the road-mortality risk is relatively low in Sweden.[4]

[Table 2 about here.]

Regarding perceived mortality risk, about half of the respondents stated that their own risk was lower than the average objective risk. However, due to a small number of large values, the estimated perceived arithmetic mean in Table 1 is higher than the objective risk. In order to decrease the distorting effect of outliers among respondents' answers, we follow previous studies and focus on geometric means (Hakes and Viscusi, 2004; Andersson and Lundborg, 2007).[5] The geometric means of perceived risk in Table 2 reveal that: (i) all female age groups, besides the youngest one, overassess their risk, (ii) all male age groups underassess their risk, and (iii) when men and women are grouped together only the age group with the lowest objective risk overassesses its risk, i.e. the age group 45-54. Most of the differences between objective and perceived risks are statistically significant. Regarding overall means, females and males over- and underassess their risks, respectively, and the full sample underassesses the mortality risk. These differences are statistically significant. Moreover, men accurately perceive their risk as higher than women's risk. The gender difference is not statistically significant, though. A scatter plot of the distribution of respondents' perceived road-mortality risk can also be seen in Figure 2.[6]

[Figure 2 about here.]

4.2 Regression results

This section contains the regression results in the following order; a probit model on the probability of underassessment, an OLS model on absolute magnitude of risk bias, and an OLS model on risk formation.[7]

[3] See, e.g., *TrafficStats* (http://www.traffic-stats.us) and/or *CARE* (http://ec.europa.eu/transport/roadsafety/).

[4] See, e.g., references in previous footnote.

[5] Arithmetic means are shown in Table 6 in the appendix.

[6] To make the scatter plot more informative, only observations lower than 40 per 100,000 are shown in Figure 2. This means excluding the answers from 32 respondents from the figure, of which 6 respondents stated that their road-mortality risk was between 1 and 20 percent.

[7] Since the probit and OLS are well known, we have not included a description of the empirical models. For a description of the models, see any textbook on econometrics.

The results of the probability of underassessment are shown in Table 3. The coefficient estimates show the marginal effect and reveal that women are less likely to state that their risk is lower than their peers (i.e. same gender and age group), that *Annual mileage* is negatively related to the perceived risk being lower than the objective risk, and that those who have a driving licence are less likely to state that their risk is lower than their peers. Thus, two of the variables related to road traffic experience are significantly negatively correlated with underassessment. Moreover, the number of children in the household aged 11-17 are also statistically significantly correlated with underassessment. Further, we find that *Income* is not statistically significant, a result that is also found when household income is instead included as a group variable.[8]

[Table 3 about here.]

Two regressions on the magnitude of risk bias were run; one for those respondents who stated that their risk was lower than the objective risk, and one for those respondents who stated that their risk was equal to or higher than the objective risk. The results are shown in Table 4 and for those respondents who perceived their risk level to be equal to or higher than their peers, no variables are statistically significant. For the other group, the bias is larger for younger respondents (reference group, *Age 18-24*), but the bias is not monotonically decreasing with age. The bias is also smaller for females, and for respondents with a university degree.

[Table 4 about here.]

Table 5 shows the results of risk perception formation. Since we only have cross sectional data, we do not have any information about prior risk assessment. The first term of Eq. (2) is, therefore, reflected by the intercept. We employ the same functional form as Hakes and Viscusi (2004) and Andersson and Lundborg (2007). To clarify, if respondents were fully informed, the intercept would be zero, and the coefficients of *ln(Objective Risk)* and *ln(Objective Risk)*^{2} would be one and zero, respectively. The results in *Risk 1*, i.e. with other covariates excluded, show that the intercept is statistically significant, whereas both objective risk variables are not statistically significant. When including the other covariates in *Risk 2*, the risk variables are still statistically insignificant and the intercept is now also statistically insignificant. A joint test of the intercept and *ln(Objective Risk)*^{2} being zero, and *ln(Objective Risk)* being

[8] Table 7 in the appendix shows results from a multinomial logistic regression, where the probability of over- and underassessment is analyzed simultaneously. We have decided to use the probability of underassessment in Table 3 as our main results for two reasons: (i) the probability of underassessment was estimated in Andersson and Lundborg (2007) and one objective of this paper is to test the robustness of their findings, and (ii) since we do not have any information about a reasonable band width for an accurate risk perception, chosen band widths will be ad hoc. In Table 7 results are shown for the case when accurate perception is defined as Perceived$\in [\text{Obj.}-1, \text{Obj.}+1]$. The robustness of the results has been tested by running regressions with band widths 1.5 and 2. Besides *Driving licence* in "Underassessors" and *Female*, the results are sensitive to the chosen band widths.

one, is rejected (p-val.< 0.001) for *Risk 1* and *2*. The results from *Risk 1* suggest that the cut-off point for over- and underassessment is $4.68 \cdot 10^{-5}$. In *Risk 2*, the only covariates that statistically influence the risk perception are *University*, *Household 0-3*, and *Driving licence*. All three variables increase the perceived risk.

[Table 5 about here.]

We do not find any statistically significant correlation between perceived and objective risk. However, the coefficient estimates from *Risk 1* show that the partial derivative for the range of the respondents is between -0.16 and 0.55.[9] The slope is zero at the risk level $3.7 \cdot 10^{-5}$ and the slope at the mean objective risk is 0.19. The slopes at the mean and for the highest risk group (men aged 20-24) suggest that 0.19 and 0.55 of the risk information is incorporated at these levels, respectively.

5 Summary and discussion

This study analyzes individuals' perception of their own road-mortality risk. Using data from a new Swedish CVM study, it replicates the analysis in Andersson and Lundborg (2007) in order to test the robustness of their results. We find that some but not all the results are robust.

Our results suggest that low and high risk individuals over- and underassess their own road-mortality risk, respectively. This finding is line with the results in Andersson and Lundborg (2007) and the empirical evidence on population mortality risks, i.e. over- and underassessment of low and high probability events, respectively (e.g. Lichtenstein et al., 1978; Hakes and Viscusi, 2004). Considering gender and age, our results show that males underassess their road-mortality risk, whereas all females, besides the youngest age group, which has the highest objective risk among females, overassess their road-mortality risk. Moreover, for three of the female age groups, 18-19, 20-24, and 65-74, the perceived mean is close to and not statistically significantly different from the objective risk. Further: (i) overall subjective risk is statistically significantly lower than objective risk, (ii) males perceive their risk to be higher than females; the difference is not statistically significant, though, (iii) males overall underassess their risk, and (iv) females overall overassess their risk. The findings (i)-(iii) are in line with Andersson and Lundborg (2007). Regarding (iv), female respondents in Andersson and Lundborg (2007) also overassessed their risk, but in their study the overassessment was not statistically significant.

The regression on the probability of underassessment shows, as expected based on the descriptive statistics, that females are less likely to underassess their risk. We also find that *Annual mileage* is negatively correlated with underassessment. Both these results support the findings in Andersson and

[9] $\frac{\partial \ln(\text{Perceived})}{\partial \ln(\text{Objective})} = \alpha_1 + 2\alpha_2 \ln(\text{Objective})$

Lundborg (2007). We also find that respondents with a driving licence are less likely to underassess their road-mortality risk. Information about whether the respondents had a driving licence was not available in the data set used in Andersson and Lundborg (2007), but the results of this study combined with the results of both studies suggest that *Annual mileage* and *Driving licence* may be proxies for risk exposure rather than skill or experience.

Regarding the size of the bias in respondents' risk perception, whereas no individual characteristics are statistically significantly correlated with the size of the bias for respondents with a subjective risk higher than or equal to the objective risk, age, gender, and a university degree are negatively correlated with the size of the bias for underassessors. The age reference group is respondents aged 18-24 and since the reference group in Andersson and Lundborg (2007) was 45-54 a direct comparison of the age effect is not relevant. The reason why age 45-54 was used in Andersson and Lundborg (2007) was because respondents in their study were informed about the objective risk of a 50 year old person. In our study respondents were informed about the population risk. We find that respondents with a university degree have a smaller bias among underassessors, a result not found in Andersson and Lundborg (2007). Regarding the results of other covariates in Andersson and Lundborg (2007); males' risk bias was larger for both groups, *Health status* was statistically significant with different signs, and *Annual mileage* negatively and *Income* positively influenced the risk bias among under- and overassessors, respectively. Hence, besides the gender effect among underassessors, the results differ.

In the regression on the formation of risk perception, we find no statistically significant correlation between perceived and objective risks. Thus, we cannot reject the fact that individuals do not update their risk perception in a Bayesian manner. However, the partial derivative, which ranges from -0.16 to 0.55, suggests a positive relationship between perceived and objective risks above the baseline risk level of $3.7 \cdot 10^{-5}$. These results are also close to those in Andersson and Lundborg (2007), where the partial derivative ranged from -0.25 to 0.55, with a positive slope above the risk level $3.8 \cdot 10^{-5}$. Regarding other covariates, having a university degree, children aged 0-3, and a driving licence increase the perception of risk. These results differ compared to the results in Andersson and Lundborg (2007), where self-reported health status, being male and having children aged 4-17 reduced the risk perception, whereas income level increased it.

6 Conclusions

Many of the findings in this study support the results in Andersson and Lundborg (2007). Over- and underassessment for low and high risk groups are confirmed, and the Bayesian updating process based on objective risk reveals similar values between the studies. The effect of individual characteristics on the probability of underassessment, size of risk bias, and risk formation for several variables differs, however, between the studies. The result that females are more likely to overassess their own mortality risk, and that individuals who drive or travel more by car are less likely to underassess their risk is robust, though.

Andersson and Lundborg (2007) examine two mortality risks, road and overall. They assumed that individuals would perceive road-traffic risk to be more controllable than overall risk, and thus to be more affected by optimism bias. Their results that road-mortality risk followed the pattern of over- and underassessment, whereas all groups underassessed overall mortality risk, therefore contradicted their expectations. Since our results confirm their findings on road-mortality risk, it may be that individuals perceive road risk as more exogenous, whereas they perceive their overall risk to be more under their own control. This could be explained by the fact that road risk is affected by exogenous factors, such as other road-users, weather conditions, etc., whereas overall risk to a large extent is determined by individual health factors, which can be influenced by decisions on smoking, exercising, etc.

A weakness of our analysis is that the objective risk is based on overall road-mortality risk, whereas the respondents in the CVM study were presented with and asked about car-mortality risk. The risk measure in the CVM questionnaire was, however, designed such that it would correspond closely to the road-mortality risk, i.e. the annual car risk ratio of 7 is close to the road risk of 6.42 per 100.000. Moreover, the respondents in Andersson and Lundborg (2007) were asked about their perception of road-mortality risk, and the fact that the patterns of risk bias and formation found in their study are supported by the results in this study suggests that the formulation may not be a crucial or decisive weakness.

This study contributes important knowledge about individuals' perception of their own mortality risk. Since individuals base their decisions on their perceived risk, our findings are important both for understanding risky behavior (Lundborg, 2007; Lundborg and Andersson, 2008; Khwaja et al., 2007; Deery, 1999) and for preference elicitation (Gayer et al., 2000; Bleichrodt and Eeckhoudt, 2006). Hence, the results are important not only from a research but also from a policy perspective.

Appendix: Arithmetic Means

[Table 6 about here.]

[Table 7 about here.]

References

Andersson, H., J. K. Hammitt, G. Lindberg, and K. Sundström: 2008, 'Willingness to Pay for Car Safety: Sensitivity to Time Framing'. Working Paper 2008:8, VTI, Dept. of Transport Economics, Stockholm, Sweden.

Andersson, H. and P. Lundborg: 2007, 'Perception of own death risk: An analysis of road-traffic and overall mortality risks'. *Journal of Risk and Uncertainty* **34**(1), 67–84.

Andersson, H.: 2005, 'The Value of Safety as Revealed in the Swedish Car Market: An Application of the Hedonic Pricing Approach'. *Journal of Risk and Uncertainty* **30**(3), 211–239.

Andersson, H.: 2007, 'Willingness to Pay for Road Safety and Estimates of the Risk of Death: Evidence from a Swedish Contingent Valuation Study'. *Accident Analysis and Prevention* **39**(4), 853–865.

Antoñanzas, F., W. K. Viscusi, J. Joan Rovira, F. J. Braña, F. Portillo, and I. Carvalho: 2000, 'Smoking Risks in Spain: Part I Perceptions of Risks to the Smoker'. *Journal of Risk and Uncertainty* **21**(2-3), 161–186.

Armantier, O.: 2006, 'Estimates of own lethal risks and anchoring effects'. *Journal of Risk and Uncertainty* **32**(1), 37–56.

Atkinson, S. E. and R. Halvorsen: 1990, 'The Valuation of Risks to Life: Evidence from the Market for Automobiles'. *Review of Economics and Statistics* **72**(1), 133–136.

Barke, R. P., H. Jenkins-Smith, and P. Slovic: 1997, 'Risk Perceptions of Men and Women Scientists'. *Social Science Quarterly* **78**(1), 167–176.

Benjamin, D., W. R. Dougan, and D. Buschena: 2001, 'Individuals' Estimates of the Risks of Death: Part II - New Evidence'. *Journal of Risk and Uncertainty* **22**(1), 35–57.

Benjamin, D. and W. R. Dougan: 1997, 'Individuals' Estimates of the Risks of Death: Part I - A Reassessment of the Previous Evidence'. *Journal of Risk and Uncertainty* **15**(2), 115–133.

Bleichrodt, H. and L. Eeckhoudt: 2006, 'Willingness to pay for reductions in health risks when probabilities are distorted'. *Health Economics Letters* **15**(2), 211–214.

Brooks, R. G., S. Jendteg, B. Lindgren, U. Persson, and S. Björk: 1991, 'EuroQol: Health-Realted Quality of Life Measurement. Results of the Swedish Questionnaire Exercise'. *Health Policy* **18**, 37–48.

Brown, S. L. and A. Cotton: 2003, 'Risk-Mitigating Beliefs, Risk Estimates, and Self-Reported Speeding in a Sample of Australian Drivers'. *Journal of Safety Research* **34**(2), 183–188.

Corso, P. S., J. K. Hammitt, and J. D. Graham: 2001, 'Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation'. *Journal of Risk and Uncertainty* **23**(2), 165–184.

Davidson, D. J. and W. R. Freudenberg: 1996, 'Gender and Environmental Risk Concerns: A Review and Analysis of Available Reserach'. *Environment and Behavior* **28**(3), 302–339.

Deery, H. A.: 1999, 'Hazard and Risk Perception among Young Novice Drivers'. *Journal of Safety Research* **30**(4), 225–236.

DeJoy, D. M.: 1992, 'An Examination of Gender Differences in Traffic Accident Risk Perception'. *Accident Analysis and Prevention* **24**(3), 237–246.

Dickie, M. and S. Gerking: 1996, 'Formation of Risk Beliefs, Joint Production and Willingness to Pay to Avoid Skin Cancer'. *Review of Economics and Statistics* **78**(3), 451–463.

Dosman, D. M., W. L. Adamowicz, and S. E. Hrudey: 2001, 'Socioeconomic Determinats of Health- and Food Safety-Related Risk Perceptions'. *Risk Analysis* **21**(2), 307–317.

Dreyfus, M. K. and W. K. Viscusi: 1995, 'Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency'. *Journal of Law and Economics* **38**(1), 79–105.

Elvik, R. and T. Vaa: 2004, *The Handbook of Road Safety Measures*. Oxford, UK: Elsevier.

EuroQol Group: 1990, 'A New Facility for the Measurement of Health-Related Quality of Life'. *Health Policy* **16**, 199–208.

Finucane, M. L., P. Slovic, C. K. Mertz, J. Flynn, and T. A. Satterfield: 2000, 'Gender, Race, and Perceived Risk: The "White Male" Effect'. *Health, Risk & Society* **2**(2), 159–172.

Flynn, J., P. Slovic, and C. K. Mertz: 1994, 'Gender, race and perception of environmental health risks'. *Risk Analysis* **14**(6), 1101–1108.

Gayer, T., J. T. Hamilton, and W. K. Viscusi: 2000, 'Private Values of Risk Tradeoffs at Superfund Sites: Housing Market Evidence on Learning About Risk'. *Review of Economics and Statistics* **82**(3), 439–451.

Glendon, A. I., L. Dorn, D. R. Davies, G. Matthews, and R. G. Taylor: 1996, 'Age and Gender Differences in Perceived Accident Likelihood and Driver Competences'. *Risk Analysis* **16**(6), 755–762.

Hakes, J. K. and W. K. Viscusi: 1997, 'Mortality Risk Perceptions: A Bayesian Reassessment'. *Journal of Risk and Uncertainty* **15**(2), 135–150.

Hakes, J. K. and W. K. Viscusi: 2004, 'Dead Reckoning: Demographic Determinants of the Accuracy of Mortality Risk Perception'. *Risk Analysis* **24**(3), 651–664.

Hersch, J.: 1998, 'Compensating differentials for gender-specific job injury risks'. *American Economic Review* **88**(3), 598–607.

Jianakoplos, N. A. and A. Bernasek: 1998, 'Are women more risk averse?'. *Economic Inquiry* **36**(4), 620–630.

Kahneman, D., P. Slovic, and A. Tversky: 1982, *Judgement under Uncertainty: Heuristics and Biases*. New York, NY, USA: Cambridge University Press.

Kahneman, D. and A. Tversky: 1979, 'Prospect Theory: An Analysis of Decision Under Risk'. *Econometrica* **47**(2), 263–291.

Khwaja, A., F. Sloan, and S. Chung: 2007, 'The relationship between individual expectations and behaviors: Mortality expectations and smoking decisions'. *Journal of Risk and Uncertainty* **35**, 179–201.

Koltowska-Häggström, M., B. Jonsson, D. Isacson, and K. Bingefors: 2007, 'Using EQ-5D To Derive Utilities For The Quality Of Life - Assessment Of Growth Hormone Deficiency In Adults (QoL-AGHDA)'. *Value in Health* **10**(1), 73–81.

Lichtenstein, S., P. Slovic, B. Fischhoff, M. Layman, and B. Combs: 1978, 'Judged Frequency of Lethal Events'. *Journal of Experimental Psychology: Human Learning and Memory* **4**(6), 551–578.

Liu, J.-T. and C.-R. Hsieh: 1995, 'Risk Perception and Smoking Behaviour: Empirical Evidence from Taiwan'. *Journal of Risk and Uncertainty* **11**(2), 139–157.

Lundborg, P. and H. Andersson: 2008, 'Gender, risk perceptions, and smoking behavior'. *Journal of Health Economics* **27**(5), 1299–1311.

Lundborg, P. and B. Lindgren: 2004, 'Do They Know What They are Doing? Risk Perceptions and Smoking Behavior Among Swedish Teenagers'. *Journal of Risk and Uncertainty* **28**(3), 261–286.

Lundborg, P.: 2007, 'Smoking, information sources, and risk perception - New results on Swedish data'. *Journal of Risk and Uncertainty* **34**(3), 217–240.

Matthews, M. L. and A. R. Moran: 1986, 'Age Differences in Male Drivers' Perception of Accident Risk: The Role of Perceived Driving Ability'. *Accident Analysis and Prevention* **18**(4), 299–313.

Morgan, M. G. and et al.: 1983, 'On Judging the Frequency of Lethal Events: A Replication'. *Risk Analysis* **3**(1), 1983.

Powell, M. and D. Ansic: 1997, 'Gender differences in risk behavior in financial decision-making: An experimental analysis'. *Journal of Economic Psychology* **18**(6), 605–628.

Rafaely, V., J. Meyer, I. Zilberman-Sandler, and S. Viener: 2008, 'Perception of traffic risks for older and younger adults'. *Accident Analysis and Prevention* **40**, 697–703.

Rosenblom, T., A. Shahar, A. Elharar, and O. Danino: 2008, 'Risk perception of driving as a function of advanced training aimed at recognizing and handling risks in demanding driving situations'. *Accident Analysis and Prevention* **40**, 697–703.

Rydenstam, K.: 2008, 'Mer jämställt i Norden än i öriga Europa?'. SCB:s tidskrift Välfärd, Nr 1.

Savage, I.: 1993, 'Demographic Influences on Risk Perceptions'. *Risk Analysis* **13**(4), 413–420.

Slimak, M. W. and T. Dietz: 2006, 'Personal Values, Beliefs, and Ecologicial Risk Perception'. *Risk Analysis* **26**(6), 1689–1705.

Slovic, P., T. Malmfors, C. K. Mertz, N. Neil, and I. F. H. Purchase: 1997, 'Evaluating Chemical Risks: Results of a Survey of the British Toxicology Society'. *Human & Experimental Toxicology* **16**, 289–304.

Slovic, P.: 1987, 'Perception of Risk'. *Science* **236**, 280–285.

Slovic, P.: 2000, *The Perception of Risk*. London, UK: Earthscan.

Smith, V. K. and F. R. Johnson: 1988, 'How do Risk Perceptions Respond to Information? The Case of Radon'. *Review of Economics and Statistics* **70**(1), 1–8.

Steger, M. A. E. and S. L. Witt: 1989, 'Gender Differences in Environmental Orientations: A Comparison of Publlics and Activists in Canada and the U.S.'. *Western Political Quarterly* **42**(4), 627–649.

Sundström, K., H. Andersson, and J. K. Hammitt: 2008, 'Swedish Consumers' Willingness to Pay for Food Safety - a Contingent Valuation Study on Salmonella Risk'. SLI - Working Paper 2008:2, Swedish

Institute for Food and Agricultural Economics (SLI), Lund, Sweden, Forthcoming.
Sunstein, C. R.: 2002, *Risk and Reason.* Cambridge, UK: Cambridge University Press.
Viscusi, W. K., J. K. Hakes, and A. Carlin: 1997, 'Measures of Mortality Risks'. *Journal of Risk and Uncertainty* **14**(3), 213–233.
Viscusi, W. K.: 1985, 'Are Individuals Bayesian Decision Makers?'. *American Economic Review* **75**(2), 381–385.
Viscusi, W. K.: 1989, 'Prospective Reference Theory: Toward an Explanation of the Paradoxes'. *Journal of Risk and Uncertainty* **2**(3), 235–263.
Viscusi, W. K.: 1991, 'Age Variation in Risk Perceptions and Smoking Decisions'. *Review of Economics and Statistics* **73**(4), 577–588.
Viscusi, W. K.: 1992, *Fatal Tradeoffs: Public & Private Responsibilities for Risk.* New York, NY, USA: Oxford University Press.
Viscusi, W. K.: 1998, *Rational Risk Policy.* New York, NY, USA: Oxford University Press.
Weinstein, N. D.: 1989, 'Optimistic Biases About Personal Risks'. *Science* **246**, 1232–1233.

Fig. 1 Nature of updating process. Source: Viscusi (1992)

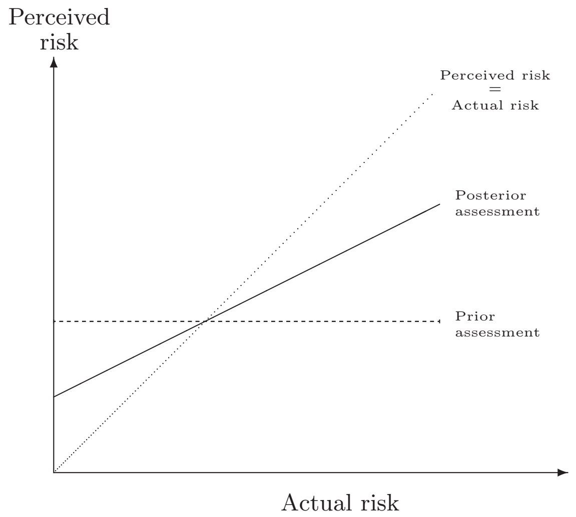

Fig. 2 Scatterplot perceived and actual risk (Perceived $< 40/100,000$)

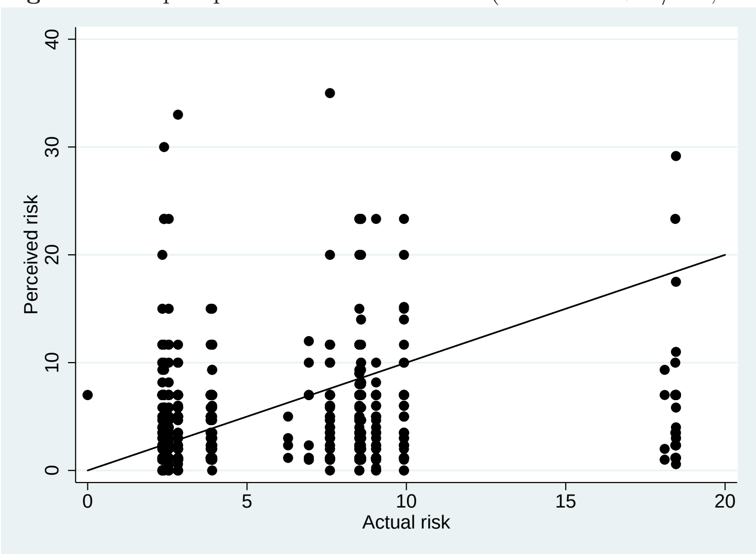

Table 1 Summary statistics

Variable	Description	Survey Mean	Survey Std. Dev.	Survey N	Sweden Mean
Road mortality	Risk perception	57.504	829.769	818	-
Road bias	Difference between objective and perceived risk in absolute terms.	51.594	829.725	818	-
Road underassess	Dummy coded as one if respondents' perceived risk lower than objective risk for own age and gender.	0.507	0.5	893	-
Age	Age of respondent.	46.583	15.439	893	44.7[b]
Health status	Respondent's self-reported health status.	89.093	12.265	842	-[c]
Female	Dummy coded as one if female.	0.575	0.495	891	49.6[b]
Income	Net monthly household income. (SEK)	25,455	13,348	880	22,639
Annual mileage	Annual mileage by car (as driver and/or passenger, 1 mile = 10 kilometers).	1,307	812	872	1,390
University	Dummy equal to one if university degree.	0.367	0.482	881	0.35
Own accident	Dummy coded as one if respondent has been injured in a traffic accident.	0.076	0.264	874	-
Family accident	Dummy coded as one if someone in respondent's household has been injured in a traffic accident.	0.108	0.31	864	-
Household 0-3	Number of household members 0-3 years of age.	0.121	0.371	840	-
Household 4-10	Number of household members 4-10 years of age.	0.232	0.66	840	-
Household 11-17	Number of household members 11-17 years of age.	0.354	0.853	840	-
Risk correct	Dummy equal to one if respondent ranked five fatality risks correctly.[a]	0.235	0.425	879	-
Driving licence	Dummy coded as one if respondent has a driving licence.	0.882	0.323	882	0.82
Access car	Dummy coded as one if respondent has access to a car in his/her household.	0.881	0.324	859	0.74

All prices are in 2006 price level. USD 1 = SEK 7.38 (www.riksbank.se, 2/11/2008)
a: The hazards were "Heart and vascular diseases", "Lung cancer", "Car accidents", "AIDS/HIV", and "Food contamination".
b: Age group 18-74.
c: Mean estimates from three other Swedish studies using the same VAS measure, 84.14 (Andersson, 2007), 85 (Koltowska-Häggström et al., 2007), and 85.37 (Brooks et al., 1991).

Table 2 Geometric mean road-mortality risk per 100,000 by sex and age groups

	Objective risk[a]			Perceived risk					
Age group	**Female**	**Male**	**Total**	**Female**	**N**	**Male**	**N**	**Total**	**N**
18-19	6.94	18.44	12.84	5.65[b]	12	5.44	8	5.57	20
20-24	3.86	18.46	11.31	4.33[b]	30	7.60	30	5.73	60
25-34	2.54	9.93	6.31	4.88	78	5.12	62	4.99	140
35-44	2.40	8.58	5.56	5.22	105	5.76	60	5.41[b]	165
45-54	2.34	7.60	5.00	4.70	79	5.91[b]	63	5.21	143
55-64	2.84	8.53	5.69	4.29	87	5.50	78	4.84[b]	166
65-74	3.91	9.05	6.33	4.08[b]	53	4.46	52	4.27[b]	105
Overall mean	2.96	9.86	6.42	4.68	444	5.53	353	5.04	797
(95% C.I.)				(4.23 : 5.19)		(4.87 : 6.27)		(4.65 : 5.46)	
Wilcoxon rank-sum[c]: p-value = 0.29									

a: Objective risk calculated on data from 1999-2006 (www.sika-institute.se, 10/10/07).
b: Not statistically significantly different from corresponding objective risk (95% C.I.).
c: H_0: Perceived(Female)=Perceived(Male)

Table 3 Probability of underassessment of mortality risk

Variable	Coeff.	
Age 25-34	0.0729	(0.0847)
Age 35-44	0.0318	(0.0852)
Age 45-54	0.0485	(0.0844)
Age 55-64	0.0162	(0.0854)
Age 65-74	0.0850	(0.0917)
Health status	1.42e-04	(0.00196)
Female	-0.598**	(0.0319)
Income	7.12e-08	(1.81e-06)
Annual mileage	-5.34e-05†	(3.03e-05)
University	-0.0598	(0.0466)
Own accident	-0.100	(0.0918)
Family accident	-0.0138	(0.0799)
Household 0-3	-0.141*	(0.0639)
Household 4-10	0.0736†	(0.0423)
Household 11-17	-0.0270	(0.0320)
Risk correct	-0.0107	(0.0520)
Driving licence	-0.180*	(0.0706)
Access car	-0.0971	(0.0798)
N	711	
$\tilde{\mathrm{R}}^2$	0.265	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%
Robust standard errors in parentheses
The coefficient estimates denote marginal effects.

Table 4 Risk bias for over- and underassessors

	Sub. risk < Obj. risk		Sub. risk ≥ Obj. risk	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
Age 25-34	-5.899**	(0.778)	161.461	(212.142)
Age 35-44	-7.015**	(0.802)	-24.418	(125.365)
Age 45-54	-6.984**	(0.805)	70.527	(144.086)
Age 55-64	-6.333**	(0.783)	430.810	(485.543)
Age 65-74	-5.960**	(0.796)	6.920	(159.359)
Health status	-0.006	(0.011)	1.919	(2.836)
Female	-3.710**	(0.292)	-590.492	(426.591)
Income	1.08e-05	(1.43e-05)	-0.003	(0.002)
Annual mileage	2.67e-04	(1.93e-04)	-0.173	(0.121)
University	-0.527†	(0.298)	-107.810	(93.564)
Own accident	-0.470	(0.540)	-169.215	(144.668)
Family accident	0.239	(0.457)	-61.425	(86.840)
Household 0-3	-0.163	(0.584)	0.399	(52.486)
Household 4-10	-0.277	(0.240)	70.369	(71.332)
Household 11-17	0.104	(0.166)	189.625	(151.081)
Risk correct	-0.104	(0.313)	17.642	(104.224)
Driving licence	-0.657	(0.495)	320.678	(276.211)
Access car	0.136	(0.498)	-739.322	(765.760)
Intercept	12.262**	(1.208)	957.908	(736.153)
N	350		317	
R^2	0.572		0.099	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%
Robust standard errors in parentheses
Dependent variables: Absolute risk bias, i.e. |Obj. risk − Sub. risk|.

Table 5 Risk perception formation

	Risk 1		Risk 2	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
ln(Objective Risk)	-0.449	(0.501)	0.366	(0.956)
ln(Objective Risk)^2	0.172	(0.152)	0.035	(0.189)
Age 25-34			-0.068	(0.241)
Age 35-44			0.016	(0.283)
Age 45-54			-0.031	(0.311)
Age 55-64			0.023	(0.251)
Age 65-74			-0.152	(0.185)
Health status			0.001	(0.004)
Female			0.477	(0.629)
Income			-1.56e-08	(3.74e-06)
Annual mileage			8.67e-05	(6.26e-05)
University			0.153†	(0.092)
Own accident			0.087	(0.135)
Family accident			-0.014	(0.140)
Household 0-3			0.199†	(0.116)
Household 4-10			-0.031	(0.069)
Household 11-17			0.080	(0.070)
Risk correct			0.099	(0.111)
Driving licence			0.479**	(0.175)
Access car			-0.005	(0.220)
Intercept	1.827**	(0.363)	-0.047	(1.622)
N	797		651	
R^2	0.007		0.048	

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%
Robust standard errors in parentheses

Table 6 Arithmetic mean road-mortality risk per 100,000 by sex and age groups

	Objective risk^a			Perceived risk					
Age group	**Female**	**Male**	**Total**	**Female**	**N**	**Male**	**N**	**Total**	**N**
18-19	6.94	18.44	12.84	101.94^b	12	7.67	8	64.23^b	20
20-24	3.86	18.46	11.31	5.36	30	53.84^b	30	29.60^b	60
25-34	2.54	9.93	6.31	21.89^b	80	7.29^b	64	15.40^b	144
35-44	2.40	8.58	5.56	8.61	106	12.45^b	60	10.00	166
45-54	2.34	7.60	5.00	147.00^b	83	88.07^b	64	120.57^b	148
55-64	2.84	8.53	5.69	7.11	90	256.61^b	81	124.61^b	172
65-74	3.91	9.05	6.33	5.42	54	9.83^b	54	7.63^b	108
Overall mean	2.96	9.86	6.42	37.76	455	82.67	361	57.63	816
(95% C.I.)				(-13.08 : 88.61)		(-29.64 : 194.97)		(0.54 : 114.71)	
Wilcoxon rank-sum^c: p-value = 0.28									

a: Objective risk calculated on data from 1999-2006 (www.sika-institute.se, 10/10/07).
b: Not statistically significantly different from corresponding objective risk (95% C.I.).
c: H_0: Perceived(Female)=Perceived(Male)

Table 7 Multinominal logit

	Underassessors		Overassessors	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
Age 25-34	0.420	(0.527)	0.215	(0.555)
Age 35-44	1.183*	(0.547)	1.197*	(0.545)
Age 45-54	0.029	(0.538)	0.227	(0.519)
Age 55-64	0.651	(0.540)	0.754	(0.571)
Age 65-74	1.298*	(0.647)	0.859	(0.683)
Health status	-0.004	(0.014)	-0.006	(0.013)
Female	-2.098**	(0.334)	1.048**	(0.337)
Income	-8.71e-06	(1.16e-05)	-4.31e-06	(1.14e-05)
Annual mileage	1.04e-04	(1.92e-04)	1.18e-04	(1.87e-04)
University	-0.125	(0.313)	0.225	(0.296)
Own accident	-0.983	(0.636)	-0.215	(0.599)
Family accident	1.288*	(0.655)	0.899	(0.679)
Household 0-3	-0.152	(0.428)	0.568	(0.395)
Household 4-10	-0.344	(0.264)	-0.422†	(0.232)
Household 11-17	-0.151	(0.206)	0.051	(0.190)
Risk correct	0.300	(0.388)	0.410	(0.372)
Driving licence	-1.362*	(0.583)	-0.383	(0.562)
Access car	0.394	(0.487)	0.536	(0.494)
Intercept	3.680**	(1.394)	0.319	(1.342)
N		667		
$\tilde{R}^2$		218.648		

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%
Accurate risk perception is the base outcome, with accurate defined as Perceived$\in$ [Obj. $- 1$, Obj. $+ 1$]