Introduction

Driving can be described by three essential tasks - navigation, guidance and control (Ogden 1996). These tasks require the driver to receive inputs from a driving environment, process them, make predictions about alternative actions, decide which are the most appropriate, execute the actions, observe their effects through feedback and process new information (Lay 1990). Essential in performing these tasks is a driver's ability to make relatively accurate estimates of the safety of the driving environment.

A driver's perception of safety in the driving environment is an important influence on driving behaviour and task performance. The question arises as how to measure the perception of safety. The perception of safety depends firstly on the nature of the information coming in but secondarily and very importantly upon the individual's emotional state and personal characteristics. Three major generic contributors to the perception of safety are the road, driver and vehicle, as shown in table 1.

Table 1 Dimension of a driving environment

Road and traffic	Driver	Vehicle
Road geometry	Driving experience	Vehicle type
Visual field structure	Physiological and psychological state	Vehicle condition
Visibility		
Road surface condition	Personal characteristics	
Traffic control device	Driving attitude	
Traffic flow		
Vehicle speed		
Weather condition		

This paper develops an empirical approach to measure a driver's perceived safety in a driving environment. The perception of safety is reviewed in the next section. An empirical approach for measuring the perception of safety is developed in section three. The empirical findings are presented in section four and the paper is concluded in the last section.

A review of the perception of safety

In the safety literature, measurement of safety is often the converse of the measurement of risk, which has produced a number of terms including objective risk, subjective risk and acceptable risk.

(1) *Objective risk*: Haight (1986) defined objective risk as the product of the *probability* of an event's occurrence and the *magnitude* (ie cost) of the event if it does occur.
(2) *Subjective risk*, also referred to as perceived risk or perception of risk, the opposite of perception of safety, is traditionally considered an individual's imperfectly informed estimate of real risk.
(3) *Acceptable risk*, also referred to as the target level of risk, is a level of risk that

society wishes to take in exchange for a level of mobility.

The definitions of three types of risk make it clear that any measurements of risk are elusive. Risk analysts frequently use the number of deaths as a measurement of objective risk, either because it is the most accurate recorded statistic or it represents the ultimate loss. However, deaths are sufficiently infrequent and their causes sufficiently diverse. Any analysis of the causes of accidents often leads to the conclusion that they are stochastic phenomenon. In the case of fatal accidents, the probability is very low. For example, there were 2017 road accident deaths on Australian roads in 1995. These deaths were spread over a population of 18.1 million, 11.0 million registered vehicles and 166.5 billion vehicle kilometers travelled (FORS 1996). Based on these statistics, there is a very small chance of fatal accident occurrence even at the worst black spots. This leads to the paradoxical result that there are "not enough accidental deaths" to produce a pattern that can serve as a reliable guide to the effectiveness of specific safety prevention measures.

As a consequence, risk analysts seek other measurements of risk such as the accident rate for injury and property damage, in ascending order of numbers but in descending order of severity compared to fatal accidents. The main accident and injury data sources are police reports, and hospital and insurance company statistics. However, all suffer from under-reporting.

When accident rates are used in the evaluation of countermeasures at specific locations, there are two possible sources of bias: regression to mean effects and accident migration. Regression to mean is a statistical phenomenon which occurs when two variables (such as the number of crashes that occur during two periods of time at a particular site) are associated with less than perfect correlation (BTCE 1995). Another source of bias is the accident migration effect. Accident migration refers to a tendency for accidents at treated black spots to decrease, with the increased number of crashes in the neighborhood of the black spot. That is, there is an apparent migration of crashes from the treated site to surrounding sites (BTCE 1995, Adams 1995).

Accident rates therefore have limitations, even retrospectively, as measures of risk. If they are low it does not necessarily mean that the risk was not high. It could mean that a high risk was perceived and avoided. Risk assessments are conditional estimates of probability and cost. Past accident rates could serve as prospective measures of objective risk only if we could assume that nothing would ever change, and only if we could assume that we learn nothing from past experience.

A small number of studies have attempted to measure the perception of safety (or subjective risk). These studies use the *electrodermal activity* as a measurement of perceived risk in a traffic environment. It is considered that emotionality (eg fear caused by danger on the road) is reflected in different degrees of perspiration and hence changes in the electrical activity of the skin. Therefore, it would be possible to measure perceived risk by looking at changes in the electrodermal activity while driving. However, it was found that the use of electrodermal activity as a measure of perceived risk is highly problematical, mainly because of the low specificity of the electrodermal responses for changes in the perceived level of risk. That is, a rise in the perceived level of risk will cause the electrodermal responses, but an electrodermal response does not necessarily indicate a rise in the perceived level of risk.

Methodology

An appeal not previously used to establish empirical bases for perceived safety is the method of stated-preference (see Louviere et al 2000 for details). A roundabout is selected as an empirical context. The attributes describing the roundabout and associated traffic were identified. We investigate a driver's perception of safety, through systematically varying the attributes describing a roundabout and associated traffic, and seeking a rating on a 5-point Likert scale from very safe to very unsafe. A face-to-face survey on a sample of Sydney drivers provides the data to estimate an ordered probit model.

Identification of attributes and levels for the experimental design: We have selected the roundabout as the empirical context. To assist in the identification and selection of attributes describing roundabout and traffic situations, we conducted a series of focus groups and pilot surveys. A broad range of attributes potentially influencing a driver's perception of safety was considered. The attributes and their levels for the final experimental design are listed in table 2.

Experimental design: Through an experimental design the attribute levels are combined into *hypothetical roundabout and traffic situations*. A full factorial design contains $3^5 * 2^4 = 3888$ possible combinations (ie five attributes with three levels and four attributes with two levels). To reduce the number of combinations to a practical size and minimise the effects of correlation, we applied a fractional factorial design, producing 27 scenarios. A typical scenario for nine attributes has the code pattern as:

1 0 1 0 1 2 0 2 0

This code describes a roundabout and traffic situation as (refer to table 2): A driver is approaching a medium-sized roundabout having two circulating lanes. The visibility to other traffic (eg from the right-side approach of the driver) is obstructed. A small-sized potentially conflicting vehicle is approaching the roundabout at a moderate speed (eg 35 km/h). The general traffic level at the roundabout is busy but there is no potentially conflicting pedestrian. The respondent is driving at a high speed (eg 60 km/h) and he or she is not in a hurry.

Considerable cognitive effort is required to understand the roundabout and traffic situation from this description. To make the task easier, we visualised the roundabout and traffic situation using video-captured real roundabout and traffic situations. A computerised survey instrument was developed that combines the visualised roundabout and traffic situation and driver's response into one survey platform. An example of an evaluation screen is shown in figure 1.

Driver's socio-economic characteristics: We contextually observed the driver's socio-

Table 2 Summary of attribute levels for experimental design

Attributes	Abbreviation	Levels and Codes
Size of the roundabout	ROUND	0 = small, 1 = medium, 2 = large
The number of circulating lanes	LANE	0 = multilane, 1 = single
Visibility to other traffic	VISIB	0 = clear, 1 = obstructed
Size of the vehicle potentially conflicting with the driver	SIZE	0 = small (eg car), 1 = medium (eg light commercial), 2 = large (eg truck)
Speed of the vehicle potentially conflicting with the driver	SPEED	0 = quick (eg 60 km/h), 1 = moderate (eg 35 km/h), 2 = slow (eg 15 km/h)
General traffic level	TRAFK	0 = light, 1 = moderate, 2 = busy
Presence of a potentially conflicting pedestrian	PEDES	0 = not presence, 1 = presence
Speed of respondent's car when approaching the roundabout	MYSPD	0 = slow (eg 15 km/h), 1 = moderate (eg 35 km/h), 2 = quick (eg 60 km/h)
The driver's time availability	HURRY	0 = not in a hurry, 1 = in a hurry

economic characteristics, including:

- *Gender*.
- *Age*: In nine categories: (1) 16-20 years (under license legislation, individuals under 16 years old are not permitted possessing a driving license, see RTA 1996); (2) 21-25 years; (3) 26-30 years; (4) 31-35 years; (5) 36-40 years; (6) 41-45 years; (7) 46-50 years; (8) 51-55 years and (9) 56 years or older.
- *Personal annual income before tax*: In seven categories: (1) $20,000 or less; (2)

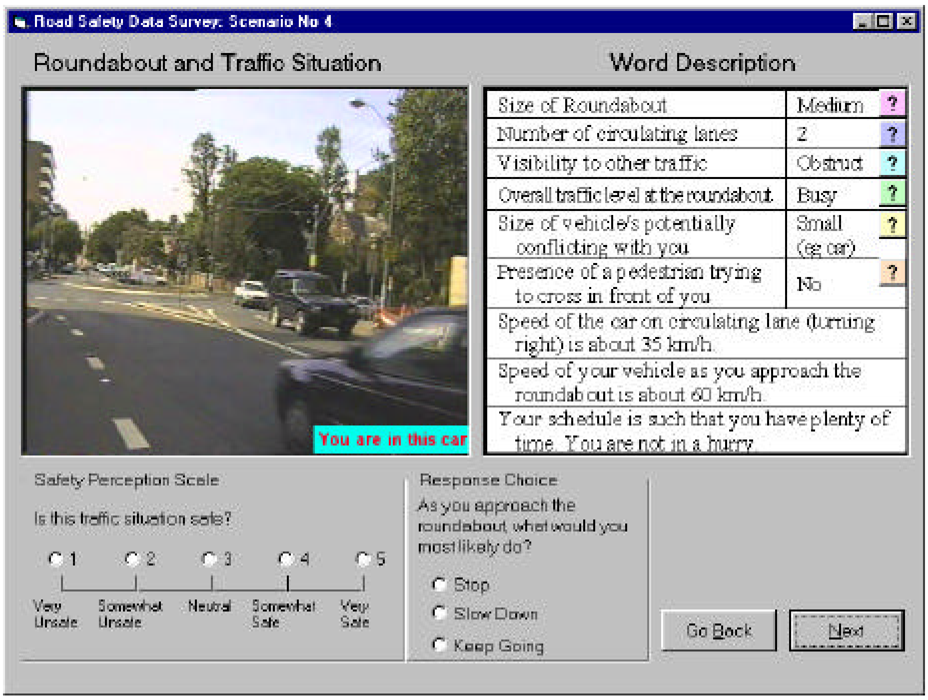

Figure 1 An example of an evaluation screen

$20,001 - $30,000; (3) $30,001 - $40,000; (4) $40,001 - $50,000; (5) $50,001 - $60,000; (6) $60,001 - $80,000; (7) $80,001 or more.
- *State and suburb*: Where a respondent lives.
- *Licence status*: In seven categories (see RTA 1996): (1) national heavy vehicle licence; (2) unrestricted gold licence; (3) unrestricted silver licence (4) provisional licence (P plate); (5) learners' licence (L plate); (6) probationary licence (eg traffic offence); (7) other licence (e.g. overseas licence).
- *Years that respondent has been driving*.
- *Accident involvement in the last two years*: In two categories: involved or not. If involved, then we sought details on who was at fault. An accident is defined as any apparently unpremeditated event resulting in death, injury or property damage ($300 or more) attributable to the movement of a vehicle on a road (RTA 1994).
- *Traffic offence in the last two years*: In two categories: committed or not. If the respondent committed a traffic offence, then we identified how many demerit points were recorded against his/her licence. A traffic offence is defined as driving behaviour that violates traffic laws and is caught by police so that demerit points are recorded against the driver's licence (RTA 1996).
- *Commuter status*. Commuter driver or not.
- *A description of the vehicle that respondent normally drives*: Including make, model, year of manufacture, number of cylinders and body type. The vehicles are classified into six categories based on collected information using the TRESIS vehicle classification scheme as a reference (ITS Sydney 2000): (1) *small*: ≤4 cylinders; (2) *medium*: 5-7 cylinders; (3) *large*: 8 cylinders; (4) *4WD*: all four wheel drive; (5) *luxury*: all of Mercedes, BMW, Rolls Royce, Jaguar, Audi, Bentley, Lexus, Daimler and Eunos and (6) *light commercial vehicle*.
- *Respondent's self-description of his/her psychological state in most situations when driving*: In five categories: (1) an aggressive driver; (2) an impatient driver; (3) a hesitant driver; (4) a slow driver and (5) a very cautious driver.

In the survey, a respondent evaluates all 27 scenarios. We face-to-face interviewed 198 Sydney drivers and obtained 194 valid responses. This produces 27 * 194 = 5238 useful observations.

Ordered probit model: We need a theoretical framework to investigate the driver's perception of safety. The perception of safety is measured on a 5-point Likert scale using a perceptual response of drivers. If we apply ordinary linear regression to examine the relationship between a choice response and experimentally designed attributes, we must assume that the safety perception scale is both continuous and interval. A number of theoretical studies have questioned the validity of the linearity assumption of such a response scale (e.g. Hensher 1989, Winship and Mare 1984). If the linear assumption is violated, ordinary least square regression may give misleading results. On the other hand, the unordered multinomial logit or probit models would fail to account for the ordinal nature of the dependent variable. An appropriate approach that both recognises the non-linearity and accommodates the ordinal property of the ordered choice response scale is the ordered response model.

In specifying an ordered probit model for drivers' perception of safety, we assume that the 5-point response scale is a non-strict monotonic transformation of an unobserved interval variable. Because perceptions of safety are ordered from very unsafe to very safe, the ordered probit model is an appropriate specification. The ordered probit model was originally developed by McKelvey and Zavoina (1975). Formally,

$$y_i^* = b' x_i + e_i \qquad (1)$$

This model expresses a respondent's preference on the ordinal ranking of y_i*. b¢ is a vector of coefficients to be estimated. x_i is a vector of attributes. y_i* is unobservable but is assumed to represent the underlying tendency of an observed phenomenon. What we can observe is,

$$\begin{aligned} y_i &= 0 \text{ if } y_i^* \le m_0 \\ &= 1 \text{ if } m_0 \le y_i^* \le m_1 \\ &= 2 \text{ if } m_1 \le y_i^* \le m_2 \\ &\;\;\ldots\ldots \\ &= J \text{ if } m_{J\text{-}1} \le y_i^* \end{aligned} \qquad (2)$$

where y_i is observed in J ordered categories, and the ms are threshold parameters to be estimated together with b¢s. There are strict assumptions on the error term e: (1) they are independent among response categories. (2) they are identically distributed. and (3) they follow the standard normal distribution.

In a particular empirical study, these assumptions may be violated. For example, the variances of e¢s may vary across individuals having different socio-economic characteristics, which lead to a different model specification. A number of authors have demonstrated that parameter estimates are generally inconsistent if the statistical assumptions on the unobserved terms in the ordered probit model do not hold (Glewwe 1997, Johnson 1996). In these cases, we have to relax some or all restrictions. If we wish to keep the ordered property of the dependent variable, a heteroskedastic ordered probit model would be an appropriate specification, i.e., the variance of the unobserved error term is a function of z_i, a set of explanatory variables. That is,

$$\text{var}(e_i) = s^2 = [\exp(g' z_i)]^2 \qquad (3)$$

The ordered model allows us to use ordinal dependent variables in such a way that explicitly recognises their ordinality and avoids arbitrary assumptions about their scale. The essence of the approach is an assumed probability distribution of the continuous variable that underlies the observed ordinal dependent variable (Hensher 2000). The underlying continuous variable is mapped into categories that define the points on the observed response scale as thresholds. These categories are ordered but separated by unknown distances. For example, we cannot say that the difference between responses 1 and 2 is identical to the difference between responses 2 and 3 or between 3 and 4.

The empirical findings

A series of model specification searches was conducted and the normality assumption tested. A heteroskedastic ordered probit model was identified as an appropriate specification. The dependent variable is a driver's perception of safety measured on a five-point Likert scale (figure 1). The attributes enter the model's index function (x_i in equation 1) and driver's socio-economic characteristics enter the model's variance function (z_i in equation 3). Attributes describing roundabout and traffic situations are effects-coded and driver's socio-economic variables are dummy-coded as shown in table 3 (see Louviere et al 2000 for details about effects-codes and dummy-codes). The estimation results are summarised in table 4.

Table 3 The description for attributes and driver's characteristics variables

Variable	Description	Values
ROUDL	Large-sized roundabout	1,0,-1
ROUDM*	Medium-sized roundabout	1,0,-1
LANE1	Single circulating lane roundabout	1,-1
CLEAR	Clear visibility to other traffic	1,-1
VEHLG	Large-sized potentially conflicting vehicle	1,0,-1
VEHMD	Medium-sized potentially conflicting vehicle	1,0,-1
SPEED	Speed of a potentially conflicting vehicle	15-60 km/h
BUSYT	Busy traffic at roundabout	1,0,-1
MODET	Moderate traffic at roundabout	1,0,-1
PEDSY	Presence of a potentially conflicting vehicle	1,-1
MYSPD	Speed of the respondent's car	15-60 km/h
HURRY*	Respondent is in a hurry	1,-1
GENDF	Female respondent	1,0
AGEY	Young drivers (25 years or younger)	1,0
AGEM*	Medium-aged drivers (25 - 50 years)	1,0
ILOW*	Low income drivers (annual income is $30,000 or less)	1,0
IMID	Medium income drivers (annual income is between $30,001 - $50,000)	1,0
RESTR	Respondent holds a restrictive licence (eg learning permit, provisional licence or probationary licence)	1,0
DRYRS	Years that respondent has been driving	1-43 years
COMYE	Commuter drivers	1,0
ACCNO	Respondent was not involved in an accident in the last two years	1,0
OFCNO*	Respondent did not commit a traffic offence in the last two years	1,0
CARSM	Respondent normally drives a small car (no. of cylinders <= 4)	1,0
PCAUT	Respondent describes her/himself as a very cautious driver in most situations when driving	1,0

* These variables are excluded in the final model due to their insignificant effects

Table 4 Estimation results of the final model for driver's safety perception

Variable	Coefficient	t-Ratio
Index function for probability		
ONE	6.1892	15.81
ROUDL	-0.5504	-13.60
LANE1	0.2362	9.95
CLEAR	1.4129	15.85
VEHLG	-0.7291	-14.62
VEHMD	0.2879	9.79
SPEED	-0.0790	-15.68
BUSYT	-0.4637	-12.10
MODET	0.1471	5.63
PEDSY	-0.7991	-15.20
MYSPD	-0.0405	-14.74
Variance function		
GENDF	0.1052	3.67
AGEY	-0.0975	-1.98
IMID	-0.1002	-3.50
RESTR	0.1275	3.30
DRYRS	0.0041	3.01
COMYE	-0.0747	-2.80
ACCNO	0.0721	1.66
CARSM	-0.0632	-2.14
PCAUT	-0.0907	-3.24
Threshold parameters for index		
μ 1	1.9244	15.28
μ 2	3.8407	15.80
μ 3	5.3374	16.06
Log-likelihood	-4722.056	
Pseudo R^2	0.5642	

All attributes are significant at the 5 percent level. A single lane roundabout, clear visibility, a medium-sized potentially conflicting vehicle and moderate traffic at roundabout have positive effects on driver's perception of safety. A large roundabout, a large-sized potentially conflicting vehicle, speed of a potentially conflicting vehicle and the respondent' car, busy traffic at roundabout and presence of potentially conflicting pedestrian have negative effects on driver's perception of safety. The effects of each attribute are discussed below:

Size of roundabout: A large roundabout is associated with lower perceived safety. When the size of the roundabout is large, the probability that the road and traffic situation is rated as safe (*somewhat safe* and *very safe*) instead of unsafe (*very unsafe, somewhat unsafe* and *neutral*) would decrease, holding other attribute levels constant. Large roundabouts are usually built at locations where traffic is heavy. The increased traffic volume increases the chance of traffic conflicting. Drivers are also more likely to drive at a higher speed as they approach a large roundabout.

Number of circulating lanes: A single circulating lane has a positive effect on driver's perception of safety. Operation at the single circulating lane roundabout is relatively simple, compared with a two or three circulating lane roundabout, where traffic weaving and lane changing greatly increase driving demands. Arndt (1998) has indicated that entering-circulating accident rates are higher at two or three lane roundabouts than at single lane roundabouts. Exiting-circulating accidents and side-swipe accidents occur predominantly at multilane roundabouts but are very rare at single lane roundabouts. The relationships between the number of circulating lanes and safety are connected to the origin-destination profile. For left turn traffic, supplying one more circulating lane would be safer. But for through and right turn traffic, one more circulating lane requires traffic weaving, making driving maneuvering difficult. If there is more than one entry lane, interaction among drivers at different approach lanes would take place.

Visibility to other traffic: Clear visibility has the largest positive coefficient among attributes. The clear visibility is essential for the safe operation of roundabouts. The sight distance is the most important factor influencing clear visibility. The visibility can deteriorate due to poor weather conditions (e.g. fog or raining) or poor road lightning. However, previous studies indicated that this attribute does not statistically significantly relate to accident rates at roundabouts (Arndt 1998). Maycock and Hall (1984) found single accident rates increase with the increase of sight distance. They could not explain this unexpected result, however suggested that the sight distance should not be deliberately reduced.

Size of a potentially conflicting vehicle: This attribute has three levels: large, medium and small. A large-sized vehicle (*VEHLG*) has a negative effect while a medium-sized vehicle (*VEHMD*) has a positive effect on the perception of safety. Due to specific properties of effects-codes (see Louviere et al 2000), we can estimate the effect of a small-sized vehicle (*VEHSM*):

$$b_{VEHSM}=(-1)\times(b_{VEHLG}+b_{VEHMD})=(-1)*(-0.7291+0.2879)=0.4412 \qquad (4)$$

That is, a small-sized vehicle has a positive effect on the perception of safety. This result is consistent with the findings of other studies. For example, Evans (1994) has compared the relative risk in two-car crashes. The severity of a collision is dependent on both the absolute mass of one vehicle and the relative masses of two colliding vehicles. The lighter the vehicle is, the riskier it is when involved in a collision. When two cars of the same mass crash into each other, their risks are equal. However, when a small car with a mass of 900 kg collides with a large car with a mass of 1800 kg, the injury risk of the small car is as high as 11.6 times that of the large car.

Speed of a potentially conflicting vehicle and the respondent's car: Both attributes have negative effects on a driver's perception of safety, suggesting that increased speed increases a driver's perceived risk. They are measured in the same unit so their effects are comparable. The ratio of the coefficients for the speed of a potentially conflicting vehicle (*SPEED*) and the speed of respondent's car (*MYSPD*) is 1.95, suggesting that a driver may see, for example, that other vehicles approaching at the speed of 45 km/h is unsafe, but possibly think it is safe when his/her car is driven at the same speed. Other studies have shown the danger in association with high speed. Fildes and Lee (1993) indicated that the force caused by a car to its counterpart in a crash is proportional to the square of its speed, and the distance that a car needs to stop is proportional to the square of its original speed. The risk of all injury accidents changes by the second power of the relative change in speeds, severe injury accidents by the third power and fatality accidents by the fourth power (Nilsson 1984). In a 60 km/h speed limited area, the risk of involvement in a casualty crash doubles with each 5 km/h increase in travelling speed above 60 km/h (Kloeden et al 1997).

General traffic level at roundabout: Busy traffic has a negative effect while moderate traffic has a positive effect on the perception of safety. Applying equation 4, we can estimate the effect of light traffic as *0.3166*, ie, a positive effect on the perception of safety. This is reasonable because increasing traffic volume increases the probability of conflicts between vehicles. Arndt (1998) indicated that approaching rear-end accidents, entering-circulating accidents, exiting-circulating accidents and side-swipe accidents at roundabouts increase as the traffic volume increases.

Presence of a potentially conflicting pedestrian: This attribute has the highest negative effect among all attribute variables, suggesting that the presence of a potentially conflicting pedestrian produces a strong unsafe perception.

The estimated coefficients can be used to investigate the relative importance of attributes on a driver's perception of safety (figure 2). Obstructed visibility, presence of a potentially conflicting pedestrian, increased speed of a potentially conflicting vehicle, a large-sized potentially conflicting vehicle, a large roundabout, busy traffic at a roundabout, increased speed of the respondent's car and a multilane roundabout contribute to a driver's unsafe perception. On the other hand, clear visibility, reduced speed of a potentially conflicting vehicle, a small roundabout, a small-sized potentially conflicting vehicle, reduced speed of the respondent's car, light traffic at roundabout, a medium-sized potentially conflicting vehicle, a single lane roundabout and moderate traffic at a roundabout contribute to a driver's safe perception.

Other socio-demographic characteristics: Nine socio-economic and driving experience variables entered the variance function of the model. These variables introduce the heterogeneity of the perception of safety between drivers with different characteristics such as age, gender, income and driving years. A smaller variance produces a more consistent choice on the safety perception scale and vise versa.

An index of perceived safety (IPS)

An important output of the estimated model is an *indicator of perceived safety* (IPS) for a roundabout and traffic scenario. The attributes of scenarios are denoted x_k, which have been observed. A driver was asked to evaluate the safety of the scenario and gave a response on the safety perception scale y_i. The relationship between y_i and x_k has been established with the ordered probit model and the preference parameters b_k have been estimated. An estimated b_k is the *theoretical contribution* of the x_k to the safety perception y_i, which can be directly translated as a change in the attribute x_k into a change in the safety perception y_i. If all estimates b_k are positioned in a particular measurement space X, $X = x_1, x_2, \ldots x_k$, each effect $b_k x_k$ is termed a *level contribution* (Achen 1982). The sum of all level contributions ($\sum b_k x_k$) represents the overall safety perception in that measurement space. The thresholds (*m*s) are eigenvalues that determine which ordered category the overall safety perception falls into. The sum of level contributions can be negative or positive. Because we intend to develop an overallsafety indicator of a road and traffic scenario, it would be inconvenient to interpret a negative indicator. Therefore, we normalised the sum of level contributions into a new scale to make all values positive. These rescaled overall safety perception values are the *indicators of perceived safety* (IPS) for the road and traffic scenario.

We investigate the driver's perception of safety at 13 typical road and traffic situations as given in table 5. Situation 1 represents an initial scenario, from which one attribute level is changed at a time. Table 6 summarises the IPS for these typical situations. Theoretically, each respondent has a specific set of IPS because each respondent has a unique set of socio-economic variables. We derived the IPS for six typical driver segments: female commuter, female non-commuter, male commuter, male non-commuter, female young, and male young drivers. Figure 4 graphically shows the IPS for six driver segments at all 13 typical road and traffic situations. The derived IPS suggests two conclusions:

(1) The IPS is sensitive to the changes in each attribute's levels. The IPS derived at situation 1 for a female driver is 12.932. Keeping other attribute levels unchanged, the IPS declines to 12.160 when the speed of a respondent' car increases from 20 km/h to 40 km/h. Each time when we change an attribute level, the IPS declines further. The worst scenario is situation 13 with the derived IPS of 0.790.

Table 5 Typical road and traffic situations under investigation

Roundabout and Traffic	Size of the roundabout	Number of circulating lanes	Visibility to other traffic	Size of other vehicle	Speed of other conflicting vehicle	Traffic at the roundabout	Presence of a pedestrian	Speed of the respondent's car
Situation1	Small	Single	Clear	Small	20	Light	Non Presence	***20***
Situation2	Small	Single	Clear	Small	20	Light	Non Presence	***40***
Situation3	Small	Single	Clear	Small	20	Light	Non Presence	***60***
Situation4	Small	Single	Clear	Small	20	Light	***Presence***	60
Situation5	Small	Single	Clear	Small	20	***Moderate***	Presence	60
Situation6	Small	Single	Clear	Small	20	***Busy***	Presence	60
Situation7	Small	Single	Clear	Small	***40***	Busy	Presence	60
Situation8	Small	Single	Clear	Small	***60***	Busy	Presence	60
Situation9	Small	Single	Clear	***Medium***	60	Busy	Presence	60
Situation10	Small	Single	Clear	***Large***	60	Busy	Presence	60
Situation11	Small	Single	***Obstructed***	Large	60	Busy	Presence	60
Situation12	Small	***Two or More***	Obstructed	Large	60	Busy	Presence	60
Situation13	***Large***	Two or More	Obstructed	Large	60	Busy	Presence	60

(2) Given a road and traffic situation, the IPS is different between drivers with different socio-economic characteristics. For any situation, young male drivers have the highest IPS and female non-commuter drivers have the lowest IPS, suggesting presence of the strong heterogeneity on the population with respect to the perception of safety. Male drivers tend to have a higher perceived safety index than females for a given scenario; commuter drivers tend to have a higher perceived safety than non-commuters; young drivers tend to have a higher perceived safety than drivers in other age categories.

Table 6 Indicator of perceived safety (IPS)for six driver segments

Scenario	Female Commuter	Female Non-Commuter	Male Commuter	Male Non-Commuter	Female Young	Male Young
Situation1	12.932	11.142	15.964	13.754	14.727	*18.179**
Situation2	12.160	10.476	15.010	12.932	13.848	17.093
Situation3	11.387	9.811	14.057	12.110	12.968	16.007
Situation4	9.862	8.497	12.174	10.488	11.231	13.863
Situation5	9.701	8.357	11.974	10.316	11.047	13.636
Situation6	9.118	7.855	11.255	9.697	10.383	12.816
Situation7	7.611	6.557	9.395	8.094	8.667	10.698
Situation8	6.104	5.259	7.534	6.491	6.951	8.580
Situation9	5.957	5.133	7.354	6.336	6.784	8.374
Situation10	4.987	4.296	6.156	5.304	5.679	7.010
Situation11	2.291	1.974	2.828	2.436	2.609	3.220
Situation12	1.840	1.585	2.271	1.957	2.095	2.586
Situation13	0.790	*0.680**	0.975	0.840	0.899	1.110

* The highest and lowest index of perceived safety

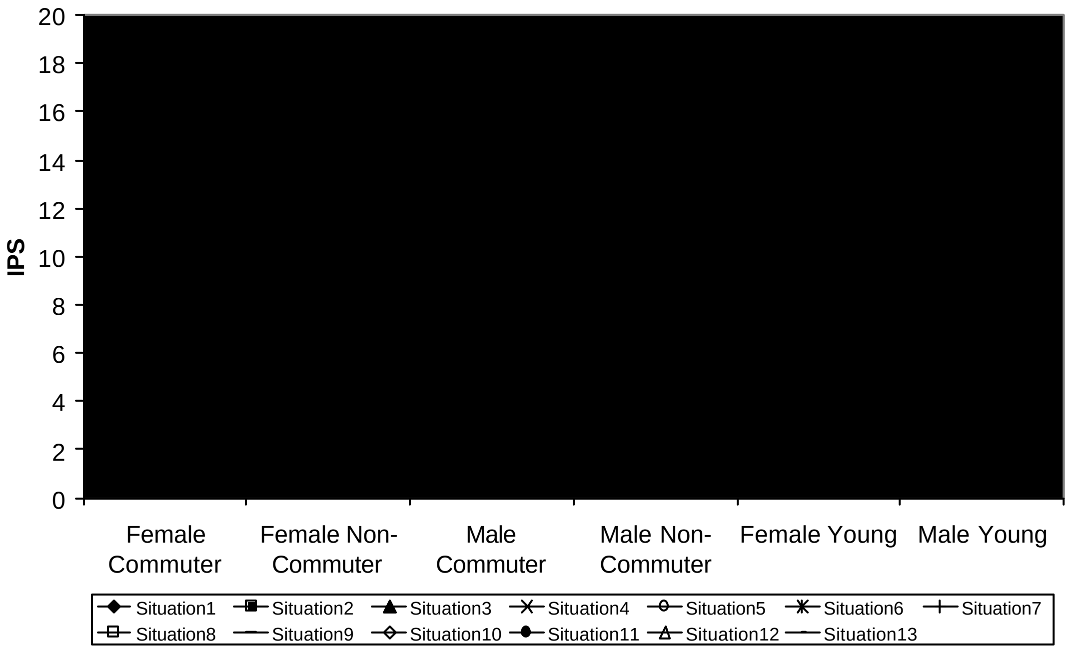

Figure 4 Indicator of perceived safety (IPS): different driver segments at all 13 typical road and traffic situations

Conclusions

The main purpose of this study is to develop a method to measure a driver's perceived safety in the road environment. The measurement of the perception of safety is an ongoing research challenge. The use of accident statistics as a preferred measure of safety has its inherent limitations (eg low accident rates do not mean low risk). The use of electrodermal activity is also problematical because of the low specificity of the electrodermal responses for changes in the perceived risk. This study has employed an alternative approach, the stated preference method, and developed an empirical approach to investigate a driver's perception of safety at specific road and traffic situations. The stated preference method overcomes many of the deficiencies in the use of accident statistics or the electrodermal response technique. Relating the perception of safety to attributes of a road and traffic situation, this study identified the contribution of each attribute to the development of an index of perceived safety (IPS). Drivers found that obstructed visibility, presence of a potentially conflicting pedestrian and increased speed represent an unsafe driving environment (with lowered IPS), suggesting that appropriate sight distance should be provided wherever possible, the pedestrian activities should be appropriate regulated and approaching speed should be limited to an appropriate level.

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