

Cognitive Failures, Driving Errors and Driving Accidents

**Teimour Allahyari
Gebrael Nasl Saraji
Javad Adl**

Department of Occupational Health, School of Public Health, Medical Sciences/Tehran
University, Iran

Mostafa Hosseini

Department of Epidemiology, School of Public Health, Medical Sciences/Tehran University, Iran

Mahmood Iravani

Department of Psychology, University of Tehran, Iran

Masood Younesian

Department of Environmental Health, School of Public Health, Medical Sciences/Tehran
University, Iran

Steven J. Kass

Department of Psychology, University of West Florida, Pensacola City, USA

Introduction. *The impact of a driver's cognitive capability on traffic safety has not been adequately studied. This study examined the relationship between cognitive failures, driving errors and accident data. **Method.** Professional drivers from Iran (160 males, ages 18–65) participated in this study. The cognitive failures questionnaire (CFQ) and the driver error questionnaire were administered. The participants were also asked other questions about personal driving information. A principal component analysis with varimax rotation was performed to determine the factor structure of the CFQ. Poisson regression models were developed to predict driving errors and accidents from total CFQ scores and the extracted factors. **Results.** Total CFQ scores were associated with driving error rates, but not with accidents. However, the 2 extracted factors suggested an increased effect on accidents and were strongly associated with driving errors. **Discussion.** Although the CFQ was not able to predict driving accidents, it could be used to identify drivers susceptible to driving errors. Further development of a driving-oriented cognitive failure scale is recommended to help identify error prone drivers. Such a scale may be beneficial to licensing authorities or for developing driver selection and training procedures for organizations.*

cognitive failure driving error driving accident taxi drivers self-report data

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Correspondence and requests for offprints should be sent to Gebrael Nasl Saraji, Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran 14155/ 6446, Iran. E-mail: <jnsaraji@sina.tums.ac.ir>.

1. INTRODUCTION

More than 70% of driving accidents are attributed to human error [1, 2]. Several researchers have explored error types and their contributions to traffic accidents [3, 4, 5, 6, 7, 8]. Sabey and Staughton listed 3 704 driver errors [3]. These errors were subjectively assessed as having contributed to the 2 130 accidents surveyed. Other studies reported four error categories that contributed to driving accidents [5, 9, 10]. These four error categories were identified as recognition errors, decision errors, performance errors, and critical nonperformance errors. Hakamies-Blomquist classified the direct causes of accidents into four categories: incapacity of action, observation error, estimation error, and driving error [6].

Basic studies on human error, from the cognitive perspective, provided helpful understanding about human error typology [11, 12]. For instance, consistent with the stages of cognitive processing of tasks, Reason classified human errors in three major categories: slips, lapses, and mistakes [11]. Slips were defined as errors of execution while lapses were identified as errors of storage. Lastly, mistakes were described as errors of planning. Reason also suggested that failure of planned actions can be divided into planning failures (i.e., mistakes) and execution failures (i.e., cognitive failures) [13].

Errors are a byproduct of human information processing or cognitive functioning of humans (see also Parker, Reason, Manstead, et al. [14]). Thus, individual differences in cognitive ability can lead to different types and rates of errors that people commit in the same situations. Broadbent, Cooper, FitzGerald, et al. noted that some people were indeed prone to established errors and were also likely to report a relatively high number of memory lapses and instances of inattention [15]. Thus, cognitive failure rates may be an indicator of the information processing capacity of humans and could therefore influence the performance of the task.

There are many studies that attempt to explore the relationship between cognitive abilities and accident involvement. In general, these efforts

indicated that cognitive failures had a major contribution to job performance and safety [16, 17, 18]. Wagenaar, Hudson, and Reason stated that cognitive failures were involved in most accidents [16]. Although Wagenaar et al.'s study was conducted in an industrial context, there is some evidence that cognitive failures are involved in traffic accidents [17]. The relations between cognitive failures and error susceptibility or commitment have been rarely researched. As Hollnagel, Kaarstad, and Lee stated, studies on human error mainly focused on taxonomy development rather than on predicting error occurrence [19].

Cognitive failures are defined as failures in perception, memory, and motor functioning, in which the action does not match the intention [15]. Thus, cognitive failures include numerous types of execution lapses: lapses in attention (i.e., failure in perception), memory (i.e., failures related to information retrieval), and motor function (i.e., the performance of unintended actions, or action slips) [20]. While cognitive failures occur frequently and many do not produce any serious consequences, some—under specific circumstances—will result in accidents. This is true when comparing driving errors and accidents rates. Whereas accidents are relatively rare, drivers routinely commit many errors. For example, they may fail to look into the rearview mirror before executing a maneuver or they may fail to notice a pedestrian crossing. However, not all of these errors result in accidents. Brown discussed how drivers in a normal traffic system tended to “forgive” others for their errors, which helped prevent collisions [4]. However, drivers with high error rates, experience high risk while driving and also create high risk situations for others even if they are not involved in an accident.

The ergonomic perspective on human error is that errors arise as a result of incompatibility between the characteristics of the human and task demands [12]. Thus, any mismatch between driver capability and task demands will increase error occurrence and potentially challenge safety [21]. One of the basic approaches to managing human error is to establish compatibility

between people's capabilities and task demands by using appropriate screening and training methods. Driver capability and competence is determined by some inherent characteristics (e.g., information processing capacity and speed) and acquired characteristics, such as vehicle control skills [21]. Therefore, determining the limitation and capabilities of drivers and understanding the influence of cognitive abilities on performance from a safety and ergonomics viewpoint is very important. To achieve this goal some tools are required.

The cognitive failures questionnaire (CFQ) is used for rating people's minor mistakes [15]. Many researchers, from different disciplines, examined the CFQ for various uses. In general, two different kinds of studies were conducted on the CFQ. The first one focused on the factor structure of the CFQ. In its original form, Broadbent et al. stated that the CFQ measured a general cognitive failure, which included perception, memory, and motor function. The findings of later studies, however, did not support this structure. It was specified that the CFQ measured multiple cognitive dimensions rather than one general factor (e.g., Matthews, Coyle, and Craig [22]; Pollina, Greene, Tunick, et al. [23]; Larson, Alderton, Neideffer, et al. [24]; Wallace, Kass, and Stanny [25]).

In a sample of 475 students Matthews et al. extracted a seven-factor solution [22]. These factors, which jointly explained 37% of the variance, were physical clumsiness, people's names, absentmindedness, lack of concentration, language, planned social interaction, and a seventh factor based on one CFQ item. Pollina et al. using a sample of 387 college students identified a five-factor solution for the CFQ, which accounted for 49% of the variance [23]. They labeled these factors as distractibility, misdirected actions, spatial/kinaesthetic memory, intelligence, and memory for names.

Larson et al. reported a three-factor solution that explained 44% of the variance in a sample of 2379 American navy recruits [24]. Yet, because there were shared items between factors 1 and 2, they reported only two interpretable factors: general cognitive failure and name processing.

Wallace et al., using a sample consisting of 335 students and U.S. Navy personnel, reported a four-factor solution, which accounted for 54% of the total variance [25]. These factors were memory, distractibility, blunders, and names.

Other types of studies on the CFQ attempted to assess a correlation between CFQ scores and other variables (e.g., performance measures and personality dimensions). Larson and Merritt found a positive and significant correlation between cognitive failure and driving accidents [17]. Another study by Larson et al. reproduced these findings and demonstrated the correlation between cognitive failure, hospitalization, and fall injuries [24]. Wallace and Vodanovich found similar results when they examined the relationship between the CFQ and safety performance at the workplace [18].

After examining the factor structure of an Iranian version of the CFQ, the present study attempts to determine the correlation of the CFQ and its subscales to driving errors and accidents. The proposed hypothesis is that the people who had committed more cognitive failures in everyday life, would have higher error rates in performing such jobs as driving, hence, they would be involved in more accidents. The other goals of this study are to determine which factors of the CFQ contribute most to driving errors and accidents, and finally to test the relationship between the CFQ and its subscales with culpable accidents.

2. METHODS

2.1. Procedure

After obtaining participants' consent, three questionnaires were administered to the subjects. They were asked to answer personal and driving- and accident-related questions. They were then instructed to rate their own minor mistakes using the CFQ reflecting on the previous 6-month period. Finally they completed the driver error questionnaire (DEQ).

Reliability of questionnaires was determined by internal consistency. Internal consistency was

measured by calculating Cronbach's reliability coefficient α , for the total score of the CFQ and DEQ as well as extracted subscales of the CFQ.

A principal component factor analysis with varimax rotation was used to determine the factor structure of the CFQ. Spearman correlation tests were used to test for associations between the CFQ and DEQ scores and accident data. Regression analyses were conducted to assess the unique contribution of the CFQ and its subscales in predicting driving errors and driving accidents.

2.2. Participants

A sample consisting of 160 male professional taxi drivers, ages 18 to 65 years ($M = 35 \pm 11.1$), with 3–44 years of driving experience ($M = 14.4 \pm 10.2$), voluntarily participated in this study. This group of drivers was selected because they had either high driving time or high exposure time. Because they drove frequently, they could potentially be involved in more dangerous situations and could pose more risks to themselves and other road users if they were prone to committing errors. Therefore, it was important to assess the type and frequency of errors committed and to determine the part those errors played in accidents. All participants reported being of normal health and working in taxi services in Tehran, Iran, at the time of the study. They reported driving a mean of 6000 km per month (range 1500–15000). For the past 3 years, 24% reported having no accidents, 22% had one accident, 18% had two accidents, and 36% had three or more accidents. On the basis of the suggested experimental research criterion, the size of this sample complied with the requirements for conducting a factor analysis [26].

2.3. Materials

2.3.1. CFQ

The Iranian version of the CFQ was translated from the original CFQ [15] and was administered to the participants. The CFQ consisted of 25 items to evaluate the frequency of lapses in perception,

memory, and motor function. Items referred to common minor mistakes such as forgetting names, failing to notice road signs, and forgetting appointments. Participants were to indicate whether those minor mistakes had happened to them in the past 6 months *very often*, *quite often*, *occasionally*, *very rarely*, or *never*. Items were rated on a 5-point Likert scale (0—*never* to 4—*very often*). Thus the participant score on the scale could range from 0 to 100. Broadbent et al. reported a good internal consistency ($\leq .89$) and test–retest reliability ($r = .82$) and good correlations with other measures of cognitive failures ($r = .62$) [15].

2.3.2. DEQ

The DEQ used in the present study was adapted from the 24-item version of the driving behavior questionnaire (DBQ) [14]. The DBQ was originally based on a theoretical taxonomy of aberrant behaviors [11]. In general, the main distinction between errors and violations in this taxonomy is based on the assumption that they have different psychological origins and need a different method of management [11]. A large number of national and international studies were conducted on the DBQ [27]. Most of them, so far, focused on its factor structure. It seems that errors and violations were stable factors of the DBQ in all studies, thus future studies need to focus more on these subscales.

In consideration of the present study's goals to focus on cognitive failures and considering Reason's [13] argument that errors originate in cognitive and mental mechanisms whereas violations have attitudinal and motivational components, items related to violations were excluded. The reconstructed questionnaire was labeled DEQ and contained a mix of items only pertaining to lapses or errors. The Appendix on p. 158 lists all 16 items used in the DEQ. Item No. 16 was added to the original items by the current authors. For scoring purposes a 5-point Likert scale (0—*never* to 4—*very often*) was implemented.

2.3.3. Driving and Accident Data

Besides age, five questions were self-reported retrospectively. These questions addressed driving experience, average mileage, total accident rate, number of at-fault accidents, and the number of traffic tickets received over the past 3 years.

3. RESULTS

Reliability analysis conducted for the instruments implemented in this study indicated coefficient α of .92 and .84 for CFQ and DEQ respectively with a mean total score for CFQ of 27.9 ± 15.7 . This mean is lower than those reported by

Wallace et al. [25] (43.4 ± 17.92) and Matthews et al. [22] (45 ± 9.7) but greater than those of Larson et al. [24] (23.6 ± 12.8) and that reported by Pollina et al. [23] (19.12).

A principal component analysis with varimax rotation was performed to determine the factor structure of the Iranian CFQ. A conservative factor loading criterion of .40 was used. Based on eigenvalues and interpretability criteria, five factors were extracted which accounted for 61% of the variance. The factor structure and item loadings are presented in Table 1.

Kaiser's measure of sampling adequacy was .88 and the Bartlett's specificity test was highly significant ($p < .01$). Those two measures indicate

TABLE 1. Factor Structure of the Iranian Cognitive Failures Questionnaire Using Principal Component Analysis With Varimax Rotation Solution ($N = 160$)

Factor	Items	Loading
Memory	13. Do you fail to see what you want in the supermarket (although it is there)?	.71
	15. Do you have trouble making up your mind?	.58
	19. Do you daydream when you ought to be listening to something?	.53
	22. Do you find you cannot quite remember something although it is on the tip of your tongue?	.73
	23. Do you find you forget what you came to the shops to buy?	.66
	24. Do you drop things?	.64
	25. Do you find you cannot think of anything to say?	.49
Lack of concentration	1. Do you read something and find you have not been thinking about it and must read it again?	.54
	3. Do you fail to notice signposts on the road?	.61
	10. Do you lose your temper and regret it?	.60
	11. Do you leave important letters unanswered for days?	.42
	12. Do you find you forget which way to turn on a road you know well but rarely use?	.58
	17. Do you forget where you put something like a newspaper or a book?	.64
	18. Do you find you accidentally throw away the thing you want and keep what you meant to throw away?	.43
Motor function	2. Do you find you forget why you went from one part of the house to another?	.54
	4. Do you find you confuse right and left when giving directions?	.69
	5. Do you bump into people?	.70
	6. Do you find you forget whether you have turned off a light or a fire or locked the door?	.62
Social interaction	16. Do you find you forget appointments?	.45
	8. Do you say something and realize afterwards that it might be taken as insulting?	.67
	9. Do you fail to hear people speaking to you when you are doing something else?	.68
	14. Do you find yourself suddenly wondering whether you have used a word correctly?	.60
Names	21. Do you start doing one thing at home and get distracted into doing something else?	.47
	7. Do you fail to listen to people's names when you meet them?	.79
	20. Do you find you forget people's names?	.62

the minimum threshold of sampling adequacy and nonzero correlation among variables. They show the appropriateness of factor analysis for this data [28].

The factor loadings of most items [20] were quite clear, except some items with a cross-loading problem (items 14, 15, 18, 19, 24, and 25). For cross-loaded items (i.e., items that had loadings of greater than .40 on more than one factor), only the higher loading was taken into account when calculating the final factor scores. Furthermore, the reliability analysis shows that all α coefficients for the five subscales were above .70 except for the names factor, which was .65.

The extracted factors were labeled memory, lack of concentration, motor function, social interaction, and names. Memory contained 7 items pertaining to forgetting and not remembering (e.g., Do you find you cannot quite remember something although it is on the tip of your tongue?) and explained 14.4% of the variance. Lack of concentration (7 items) related to attention and concentration (e.g., failing to notice signposts on the road and not concentrating on reading). This factor accounted for 14% of the variance. The third factor, motor function (5 items), contained items related to confusing and motor mnemonics (e.g., confusing right and left when giving directions). This factor explained 11.7% of the variance. The items loading highest on factor 4 was social interaction (8, 9, and 14), which accounted for 10% of the variance. The final factor, names (2 items), related to memory for names and explained 7% of the variance. This factor has been found consistently in every factor structure that has been published on the CFQ.

To examine the relationship between cognitive failures and the total number of accidents, Spearman correlation coefficient was computed. However, no significant correlations were found between the total CFQ score and the total number of driving accidents. Total CFQ scores and at-fault accidents did not show any significant correlations either. We did not find any variations in these results after adjusting for age and driving experience.

In attempting to specify the contribution of CFQ subscales to accidents, we conducted univariate analyses, which revealed that the relationship of accidents and all five subscales of the CFQ were significant. Then, these factors were checked in a multivariate Poisson regression and forward stepwise procedures were used to find the most effective factors. All factors except motor function entered the model. Lack of concentration and social interaction suggested an increasing effect on accidents.

Poisson regression analysis was repeated for at-fault accidents as a dependent variable. Only social interaction entered this model ($\alpha = .071$, $p = .002$).

As expected, a positive and significant correlation was found between the CFQ total score and driving error rates as measured with the DEQ ($r = .51$, $p = .00$; two-tailed) (Figure 1). Then a regression analysis was used to predict driving errors by CFQ scores. The results suggested that total CFQ scores were a significant predictor of driving errors, $F(1, 146) = 48.42$; $p < .001$; $R = .51$.

For all the factors extracted, stepwise multiple regression analyses were implemented to assess simultaneously the relative contribution of each factor to driving error rates. To do this, factor scores were computed for each person. Then, a stepwise regression analysis was performed for these factor scores. When all five factors were considered simultaneously only the factors of lack of concentration and social interaction entered the multiple regression equation. Lack of concentration showed the strongest correlation with driving errors. Hence, this factor was the first predictor that entered into the regression equation. This model explained 26% of the variance in driving error rates, $F(1, 146) = 53.9$; $p < .01$.

The second factor with a significant partial correlation with driving error rate was the social interaction factor ($r = .24$, $p < .01$); this was the second predictor that entered into the equation. About 31% of the variance in driving error rates could be explained with the regression model with these two factors, $F(2, 146) = 32.92$; $p < .01$.

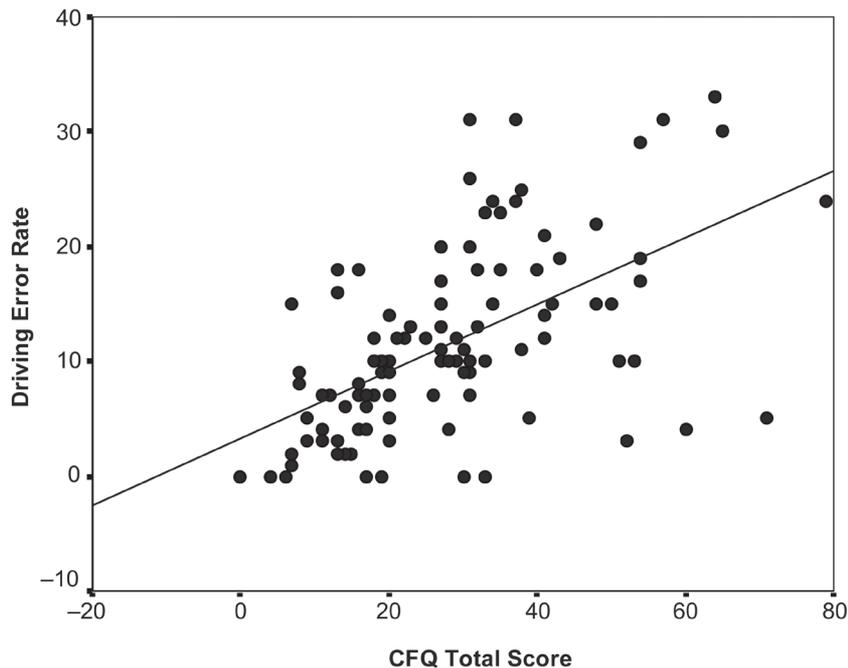


Figure 1. Correlation between cognitive failures questionnaire (CFQ) total scores and driving error rates as measured with the driver error questionnaire for 160 drivers.

4. DISCUSSION

The results of this study confirm other researchers' findings that the CFQ measures multiple dimensions of cognitive failure rather than a single dimension [22, 23, 25]. This study, using the Iranian version of the test, explained more of the total variance in comparison to previous studies.

The correlation of total CFQ scores with driving accidents in this study does not support the hypothesis that the total CFQ score can be used to predict driving accidents. This is different from the findings of Larson et al. [24] and Wallace and Vodanovich [18], but with regard to predictive ability of CFQ subscales it confirms the findings of these researchers. Wallace and Vodanovich [18] found that only their blunders factor of their solution significantly predicted automobile accidents. This factor has a great deal of overlapping items with the social interaction factor which also proved to be a significant predictor here. In addition to this factor, we also found other factors, e.g., lack of concentration and memory, which could be related to accident

liability (Table 2). In general, these findings indicated that an overall score of cognitive failures was not a good predictor of accidents, but the subscales were. Therefore for accident prediction we must focus on CFQ subscales. Subscale scores may indicate drivers' likelihood of future involvement in certain types of accidents. For example, the lack of concentration subscale may be predictive of driving violations that involve attention lapses (e.g., running stop signs and failure to yield). Future research must explore the link between CFQ subscales and various types of accidents.

TABLE 2. Predictors of Driving Accidents by Cognitive Failures Questionnaire Subscales for Professional Drivers (Stepwise Poisson Regression Analysis)

Variable	Coefficient	SE	P Value
Constant	.53	.124	<.0001
Memory	-.05	.017	.0010
Lack of concentration	.04	.013	.0010
Social interaction	.10	.023	<.0001
Names	-.09	.038	.0100

Taking into account the concept of culpability of accidents, this study attempted to examine association of the total CFQ score and at-fault accidents; however, it could not find any differences in comparison to the total number of accidents; neither was significant. In other words, the predictive ability of the CFQ for total number of accidents and culpable accidents is the same. Despite the importance of culpability in accidents, efforts to find a strong relationship between predictors and this type of accident in comparison to total accident rate had inconsistent results [29]. However, the present study provided further evidence on the claim that total CFQ score was not related to accidents. It should be noted that lack of consideration to accident data distribution probably resulted in biased findings. af Wählberg [29] claims this oversight entered in some previous studies.

In general, this study revealed that the total CFQ score was an appropriate tool for identifying drivers susceptible to driving errors but could not be an appropriate instrument for predicting automobile accidents. However, four of the five subscales derived from the CFQ in this study significantly entered the prediction model. This finding suggests that human error studies should focus on finding those cognitive factors that contribute to driving errors and accidents.

Likewise, a strong and positive correlation which was found between cognitive failure and driving error rates confirmed the hypothesis that people with more cognitive failure committed more driving errors. In the prediction of driving error rates, the two subscales of the lack of concentration and social interaction were significant (Table 3). The driver's lack of concentration has been frequently cited as

a major cause of motor vehicle accidents [30]. The social interaction factor indicates a poor social interaction that probably interrelates with other characteristics such as low self-confidence, clumsiness, and impulsivity, which makes a person susceptible to driving errors and accidents.

However, one limitation of the present study is the reliance on self-reporting of the accidents and driving errors, which may be confounded by the very same factor it aims to measure. Self-report data are bound to be imprecise due to two types of factors: cognitive factors or memory distortions, and situational factors such as anonymity, social desirability bias in responses, and confidentiality issues [31].

Subsequent research could be designed on the basis of accurate and reliable accident data which may be acquired through police traffic reports and insurance companies. Driving errors or behavior data can be collected with other methods such as naturalistic study, in-car observation, in-car recording, or through simulating driving tasks in a laboratory setting which is better than relying on self-reports alone. In addition, further studies are needed to develop a driving-oriented cognitive failure questionnaire to assist a precise assessment of cognitive failures in the driving context.

In summary, this study supports the possibility of using the CFQ as a prescreening tool, and in facilitating driver selection and training programs, especially for professional driving jobs that have little tolerance for error. This effort helps to identify error-prone drivers and reduce the frequency of driving error and accident occurrence. Also, the use of CFQ could help plan for remediation of error problems through retraining, redesign of the human-machine interface, memory aids, and better access to traffic-related information.

TABLE 3. Predictors of Driving Error by Cognitive Failures Questionnaire Subscales for Professional Drivers (Stepwise Regression Analysis)

Variable	Coefficient	SE	PValue
Lack of concentration	0.42	0.11	<.0001
Social interaction	0.61	0.20	.0030
Constant	4.28	1.13	<.0001

Notes. $F(2,146) = 32.92$; adjusted $R^2 = .30$.

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APPENDIX

Items from the driver error questionnaire (adapted from the driver behavior questionnaire)

1. You attempt to drive away from traffic lights in third gear.
2. You realize that you have no clear recollection of the road along which you have just been traveling.
3. You forget where you left your car in car park.
4. You switch on one thing, such as the headlights, when you mean to switch on something else, such as wipers.
5. You fail to notice that pedestrians are crossing when you turn into a side street from a main road.
6. You misread the signs and exit from a roundabout on the wrong road.
7. On driving left, you nearly hit a cyclist who has come by your side.
8. Queuing to turn left onto a main road, you pay such attention to the main stream of traffic that you nearly hit the car in front of you.
9. You underestimate the speed of an oncoming vehicle when overtaking.
10. When reversing, you hit something that you had not previously seen.
11. Intending to drive to destination A, you “wake up” to find yourself on the road to destination B, perhaps the latter being your more usual destination.
12. You fail to check your rearview mirror before pulling out, changing lanes, etc.
13. You brake too quickly on a slippery road, or steer the wrong way into a skid.
14. You miss a “Give way” sign and narrowly avoid colliding with traffic with the right of way.
15. You get into the wrong lane approaching a roundabout or an intersection.
16. You fail to use hand brake when parking the car.