Chapter 7
Driving Behaviour and Changing Behaviour

Abstract Automotive industry and policy makers have taken all kinds of measures to reduce the number of (fatal) accidents and make driving safer. However, drivers are a central factor in establishing safety. While safety measures are important in making driving safer, if drivers do not comply, efforts by industry and policy makers may not be effective. In this chapter, we look at driving behaviour, in particular at driving styles. We discuss the phenomenon of behavioural adaptation and look at efforts to apply technology to make drivers change their behaviour.

The occurrence of accidents has led to the development of measures to improve safety, both passive and active safety measures. Passive safety measures aim to mitigate the effects of an accident. Examples are safety belts, airbags and pedestrian protection systems. Active safety systems aim to prevent the occurrence of an accident. Examples are electronic stability control, anti-lock braking systems, automatic emergency braking, but also head-up displays and blind-spot warning systems.

Although it is not always easy to measure the effect of particular measures, still there is evidence that they may have drastic effects on safety. For example, Fig. 7.1 shows the influence of seatbelt compliance on the number of casualties in 46 high income countries.

There are a number of things to say about driving safety. In the first place, while safety measures aim to improve safety, the introduced measures may also have unexpected effects, in that people adapt their behaviour to the new situation resulting from the introduction of the measures, therewith reducing the effectiveness of the safety measure. This phenomenon is known as behavioural adaptation. In the second place, not all people drive in the same way. Instead, people have different driving styles, and some driving styles may be associated with higher risk of accidents. Both the phenomenon of behavioural adaptation and the existence of different driving styles have led to the insight that improving traffic safety may not just be a matter of introducing more and more passive and active safety systems, but that technology may also contribute to actively influencing people's attitudes and behaviour through so-called persuasive technology. In this chapter, we will go into these developments.

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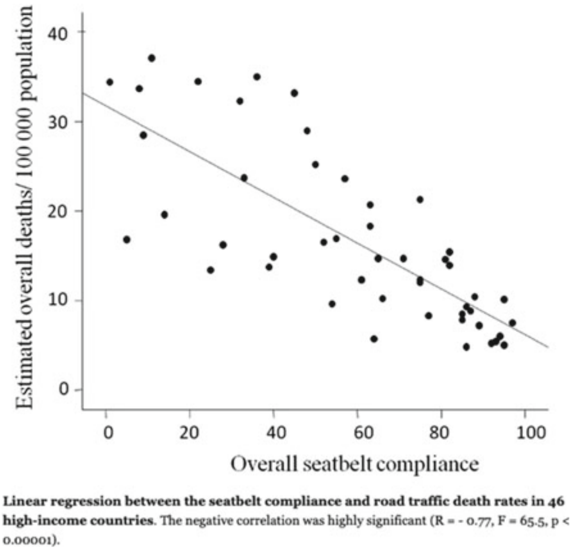


Fig. 7.1 Relation between seatbelt compliance and estimated deaths in 46 high-income countries. *Source* Abbas et al. (2011). Licensed through Creative Commons Attribution License

7.1 Safety Measures and Behavioural Adaptation

Kulmala (2010) lists a number of ways in which safety systems may affect safety. The most important ones are the following.

1. Certain measures may influence the modal choice or the route choice. For instance, speed limits and other measures to reduce the speed in residential areas may lead drivers to take another route, therewith increasing the safety in the residential area.
2. Intelligent injury reduction systems and crash reporting may mitigate accident consequences.
3. Systems that give information, advice and assistance, or that take over part of the task may influence the driving task. For example, a speed alert by an active acceleration pedal may lead the driver to reduce the average speed.

As already mentioned above, not all ways in which safety systems affect safety are positive. Examples are the following:

4. Active safety systems may lead to long-term modification of driving behaviour. For instance, users of Adaptive Cruise Control may rely on the system so much that their response time to hazards increases.
5. Safety systems may lead drivers to change their behaviour, which in turn is imitated by other drivers whose vehicle does not have such systems. For instance, Electronic Stability Control may lead drivers to drive faster through curves on wet roads, and this may make other drivers feel that they can also drive at higher speeds. Similarly, Connected Driving systems, by which vehicles receive information about deceleration and braking from the leading vehicle, may make

drivers drive at shorter distances, but this may lead drivers of non-connected vehicles to also drive at shorter distances.
6. Similarly, knowledge about the presence of safety systems may lead vulnerable road users (bicyclists, pedestrians) to change their behaviour. For instance, knowledge that automated vehicles are equipped with automatic emergency braking systems may lead pedestrians to take more risk in crossing the street.

In general, a safety measure targets an intended effect, which is to increase safety. This is called the "engineering effect". For example, the speed limits and additional measures under point 1 above may lead drivers to reduce their speed in a residential area. However, the same measure may also have other effects, and this is called "behavioural adaptation". These unintended effects may be positive. For instance, drivers may choose a different route, and this may have a positive effect on traffic safety in the residential area (although this may be at the expense of traffic safety at the alternative route). Or they may decide to choose a different transport modality (public transport) altogether, as a result of the introduction of the measure. However, more often the effects are negative, as mentioned under points 4–6 above, affecting traffic safety negatively.

Usually, the positive and negative effects may both occur at the same time, so that it becomes important to find out what the net result of a certain measure is. One way to do this is to measure the number of accidents before and after the introduction of a particular measure. However, at the same time other things may also change: other measures may have been introduced, the weather may have changed, there may be road construction works, and these confounding factors may influence traffic safety as well, so that obtaining an accurate estimate of the effect of a particular measure may be difficult. Obviously, however, this should not keep policy makers and engineers from thinking about and implementing measures and systems that aim to make traffic safer.

One thing to note in this context is that the occurrence of behavioural adaptation in influenced by a number of factors:

1. The size of the intended effect (the engineering effect) of the measure. An improvement of the car's lighting system will likely lead to larger behavioural adaptation by night than during daytime: the increase in speed that a driver exhibits when has car is equipped with such an improved lighting system may be larger at night than during daytime.
2. How easily the measure is detected. A collapsible steering column aiming to mitigate consequences of an accident may not even be noticed, and not lead drivers to change their behaviour.
3. Whether there are already behaviours that pave the way for a certain measure. Mandatory periodic inspection of the car aimed to check whether the car is still safe to drive may be more easily accepted because car owners bring their vehicle to the dealer for its annual check.
4. Whether the measure intends to prevent accidents or to mitigate the effect of accidents. Measures that intend to prevent accidents by making the car easier to control in adverse circumstances, such as Electronic Stability Control, are

more likely to lead to behavioural adaptation than measures that aim to reduce the severity of injuries in accidents, such as air bags.

5. Utility gain. Changes in behaviour that lead to utility gains such as a reduction in travel time are more likely than changes that do not lead to utility gains.

While behavioural adaptation with adverse consequences cannot be avoided, at least insight in factors contributing to its occurrence can help to anticipate the occurrence of behavioural adaptation and to think about ways to mitigate its effects.

7.2 Driving Styles

Everyone who is a regular driver knows from own experience that there are clear differences between people in the way they drive. Most people consider themselves to be good drivers, and most people dislike driving behind the proverbial 80-year old lady who drives slowly and overly cautious. Also, we all know the stories about young people going out on Saturday evening and exhibiting risky behaviour that we consider irresponsible and dangerous. Finally, there are also the stories reflecting our cultural stereotypes about driving behaviour in other countries. All these stories relate to the concept of driving styles. Generally speaking, driving styles are behaviours that people display typically, that is, under normal circumstances. This definition also implies that a particular person, who has a particular driving style, does not display this behaviour all the time. For instance, a newly married person who displays a more assertive driving style under normal circumstances, may show very different behaviour when picking up his parents in law from the railroad station. Furthermore, the connection between driving and risk-taking mentioned above has been the topic of much research, aiming to understand the factors determining the occurrence of risky driving and to propose and evaluate measures to further safe driving.

When conducting research into differences in the way people drive, there are a number of questions. The first question is how to measure driving styles. The second question is which are the actual different driving styles that have been inferred from these measurements. The third question is which factors govern the occurrence of particular driving styles. And the fourth question is how safe driving styles can be promoted and how driving styles that may have negative consequences can be countered.

There are typically two ways to measure driving styles. One is through self-report, the other is through measurements of the driving behaviour. Several self-report questionnaires have been proposed; commonly used ones are the Driver Behaviour Questionnaire (DBQ, Reason et al. 1990), the Driving Style Questionnaire (DSQ, Ishibashi et al. 2002), the Multi-dimensional Driving Style Inventory (MDSI, Taubman-Ben-Ari et al. 2004). Such questionnaires consist of a number of items describing relevant driving behaviours and ask respondents to respond by a scalar answer ranging from “not at all” to “very frequently”. The data are then submitted to a factor analysis and the factors emerging from the analysis are then interpreted by mapping them onto dimensions of driving behaviours. The DBQ asks for the occurrence of different types of errors and maps the outcomes onto three types of errors: deliberate violations (e.g., “deliberately violating speed limits at late night”), dangerous errors (e.g., “failing to note a pedestrian crossing”) and ‘silly’ errors (e.g., “forgetting where one’s car is parked”). The DSQ maps the result onto six dimensions: speed (e.g., “Do you drive fast”), calmness (e.g., “Do you remain calm when things happen very quickly and there is little time to think”), social resistance (e.g., “Do you dislike people giving advice about your driving”), focus (e.g., “Do you drive cautious” and “Do you find it easy to ignore distractions while driving”), planning (e.g., “How often do you set out on an unfamiliar journey without first looking at a map”), and deviance (e.g., “Do you ever drive through a traffic light after it has turned red”). The original MDSI mapped the results onto eight dimensions: Risky driving (e.g., “like to take risks while driving”), Angry driving (e.g., “swear at other drivers”), Careful driving (e.g., “always ready to react to unexpected manoeuvres by other drivers”), Patient driving (e.g., “at an intersection where I have to give right-of-way to oncoming traffic, I wait patiently for cross-traffic to pass”), Anxious driving (e.g., “feel distressed while driving”), Dissociative driving (e.g., “intend to switch on the windscreen wipers, but switch on the lights instead”), High-Velocity driving (e.g., “when in a traffic jam and the lane next to me starts to move, I try to move into that lane as soon as possible”) and Distress-reduction driving (e.g., “while driving, I try to relax myself”). There have been later evaluations of the MDSI in different countries, from which smaller numbers of reliable dimensions emerged. Importantly, the underlying idea of such questionnaires is that driving style is not a uni-dimensional concept but multi-dimensional: one is not either an aggressive or risky or calm driver, but for each driver a multi-dimensional profile arises from the questionnaire. On the other hand, certain correlations may be expected to exist, and Taubman-Ben-Ari and Skvirsky (2016) arrive at four main styles: Reckless and careless driving style, Anxious driving style, Angry and hostile driving style, and Careful and patient driving style.

Most studies measuring driving styles from observable behaviour are conducted using driving simulators, but studies of real-life driving behaviour have been conducted as well, collecting data from the CANbus or from dedicated in-vehicle data recorders. The disadvantage of driving simulator studies is that the behaviour of participants in such studies may not be representative of their normal driving behaviour, also because of limitations in the fidelity of the simulation, but the advantage of driving simulator studies is that the situations to be studied are under control of the researchers. In real life, the situations in which the relevant behaviour (such as “when in a traffic jam and the lane next to me starts to move, I try to move into that lane as soon as possible”) can be measured may occur infrequently, so that only few measurements can be collected from which to determine the individual’s driving style. As a result, studies aiming to derive driving styles from observable behaviour in real-life situations have focused on a few main dimensions, such as calm/patient versus aggressive/hostile, and the main indicators are acceleration behaviour, speed in turns, distance and the size of critical gaps.

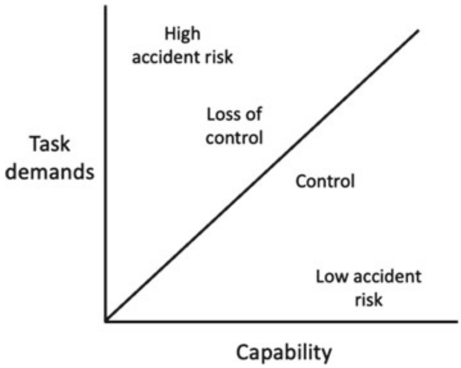
A third way to infer driving styles from behavioural indicators is to look at the involvement in car crashes and the individual’s history of traffic violations.

Studies have been conducted on the question of whether outcomes from self-report methods have external validity, that is, whether they correlate with the outcomes studies of observable behaviour. Some success has been achieved in this respect, although usually the amount of variance explained is rather modest, and again the evidence supports only a few main dimensions. This may also be due to the fact that behaviours such as "Do you dislike people giving advice about your driving" (DSQ) and "swear at other drivers" (MDSI) are difficult to observe, both in driving simulator studies and in real life. What matters most, from an interaction design perspective, is whether there is a relation between driving style and involvement in accidents, and indeed there is evidence that observable behaviours such as acceleration behaviour, speed in turns, distance and the size of critical gaps have predictive value for involvement in accidents. Thus, the ability to derive data concerning these behaviours from the CANbus or from dedicated in-vehicle data recorders offers opportunities for the design of applications that aim to counter adverse driving behaviour. In fact, such data have been used by insurance companies to influence driving behaviour by rewarding safe driving behaviour by lower insurance rates and in this way preventing involvement in accidents, which is to be preferred over the current practice where the insurance rate goes up *after* involvement in an accident.

The third question concerns the factors that govern the occurrence of driving styles. Research indicates that driving styles are conditioned by several demographic and personality variables (Taubman-Ben-Ari and Skvirsky 2016). Demographic variables are most notably age and gender. Men have a higher tendency to engage in risky and angry driving than women. Also, younger drivers have a higher tendency to engage in risky and angry driving than older drivers. As a result, younger male drivers show the highest incidence of risky driving. However, not all young male drivers exhibit risky driving, so the next question concerns which personality variables differentiate risky drivers from more calm and careful drivers. Both the reckless/careless (risky) and the aggressive/hostile driving styles have been found to correlate well with sensation-seeking, and to correlate inversely with the traits of agreeableness and conscientiousness as emerging from the Big Five personality inventory. The occurrence of an anxious driving style has been found to correlate well with neuroticism as measured by the Big Five personality inventory. And, as might be expected, the careful and patient driving style has been found to correlate with the traits of agreeableness and conscientiousness as emerging from the Big Five personality inventory.

Further contributions to the understanding of driving styles have been made by Wilde and Fuller. Wilde (1982) argues that, in order to predict and understand the effect of safety measures, we need to understand how driving behaviour arises. He proposes that one factor accounting for differences between drivers in the way they drive arises from the target level of accident risk they set for themselves. This is their accepted or preferred target risk. Among the factors that determine the target risk are person-related factors such as culture, gender, age, attitude, personality traits, but also transient states such as fatigue, being in a hurry and frustration. When driving, people compare the perceived accident risk with the target, and adjust their behaviour to reduce the discrepancy between perceived and target risk. If, for whatever reason, the perceived accident risk is lower than the accident risk they find acceptable, they

Fig. 7.2 Fuller's task capability interface model



will adjust their driving behaviour so that the perceived risk increases. In other words, they will drive more riskily. If the perceived accident risk is higher than the accident risk they find acceptable, they will adjust their driving behaviour so as to reduce the perceived risk. In other words, they will drive less riskily. Summarizing: people aim for homeostasis, aiming to maintain a particular state that they consider optimal, and adjust their behaviour in case of perceived discrepancy with this optimal state. From this it is clear that safety measures that affect people's perceived accident risk, will make them adjust their behaviour and drive more riskily to restore the optimal state. The extent to which they do this depends on the size of the effect of the measure on the perceived risk, as we have seen above.

Likewise, Fuller (2005) proposes that drivers select a preferred level of task difficulty and adjust their driving behaviour such that the difficulty of the driving task does not exceed their capability as judged by themselves (see Fig. 7.2). If the driving task becomes more difficult, e.g., because of adverse weather conditions, they will adjust their driving behaviour so that their driving skills again match the challenges posed by the task. In this view, differences between people arise from differences in their preferred level of task difficulty and differences in their level of skill as perceived by themselves. People who overestimate their own skill will be inclined to take more risk than people who have a more adequate estimate of their own skill. For Fuller, as for Wilde, measures that aim to improve traffic safety may not have the desired effect. For Fuller, if such measures lower the perceived task difficulty and therewith the demands posed by the driving task, people will adjust their behaviour and drive more riskily, so that again there is a balance between task demands and driving skills.

The important contribution of both Wilde and Fuller is to point out that, in order to devise effective measures to improve traffic safety, we need to anticipate the possibility of behavioural adaptation. Simple measures applying in the same way to everybody may not achieve the desired effect because of this behavioural adaptation. Of course, the positive (intended) effect may outweigh the negative (unintended) effect, so that the net result of a particular measure may still be positive. For instance, even if drivers increase their speed if dangerous curves in a highway are removed and some accidents result from this higher speed, the net result in terms of lower accident risk may still be positive. But both Wilde and Fuller argue that, in order to increase the likelihood that safety measures will have the desired effect, people's desire to be safe must be influenced, that is, they must change their target level of risk or the target level of task difficulty.

The discussion of the effects of safety measures has brought us to the fourth question, of how safe driving can be promoted and unsafe driving can be countered. In Sect. 7.3 we will look at some more recent approaches to this challenge, by means of smart technology enabling a more personalised approach towards attitudinal and behavioural change.

7.3 Changing Behaviour

The idea that design should not only aim to adjust technology to the needs of people or to create good user experiences, but may also be deployed to change behaviour is associated primarily with the work on Persuasive Technology by Fogg (2003). According to Fogg, technology may influence people in three different ways. Technology may provide people with *tools*, and as such shape the way people perform certain tasks, making it easier to perform the task or restructuring the way the task is performed. For instance, automatic transmission makes the gearing of the vehicle easier compared to manual transmission. Also, a navigation system may influence where and how people drive by offering navigation advice and speed limit information. Secondly, technology may function as *media* that convey a certain message. For instance, the Neon Drunk Driver Simulator was developed to simulate the experience of drunk driving for university students. A real automobile was prepared to respond unpredictably and sluggishly to the driver's inputs, and this vehicle was then taken to university campuses for students to experience drunk driving on a dedicated track on the campus. The message came across to some extent: It was found that the experience did not make students change their intention to drive when having drunk, but at least they said that they would think twice before getting into a car with a drunk fellow student as driver. Thirdly, technology may function as a *social actor*, and offer suggestions for change and rewards. For instance, a driver coach system may monitor the driver's driving behaviour and provide feedback and suggestions for change. Social actors may induce behavioural change in a number of ways, including praise ("Congratulations" or "Well done") and authority ("You should …").

There have been a number of applications of technology as *social actors* in the context of driving, primarily for two purposes, sustainability and safety. Nowadays, truck manufacturers offer systems that provide feedback to truck drivers in order to make them adjust their braking and gearing behaviour and thus reduce fuel consumption. From a design perspective, it should be kept in mind that the savings do not only benefit the owner of the truck but that the drivers themselves also benefit from the savings. Another application, EcoDrive, was launched by Fiat in 2008 (Fig. 7.3 Left). They developed an application by which drivers could store data about their

Fig. 7.3 Left: Fiat's EcoDrive system. *Source* https://www.baxtr.co/fiat-ecodrive. Reprinted with permission from AKQA/Fiat. Right: Honda's Eco Assist system. *Source* Honda Global, Reprinted with permission. https://global.honda/newsroom/news/2008/4081120aeng.html

driving behaviour on a USB stick and, after reaching their destination, upload the data in their personal computer and compare it to the behaviour of other drivers, thus turning sustainable driving into a contest and applying the *persuasive strategies* of comparison and competition. The application of such a *gamification* approach turned out to be very successful. Likewise, Honda offers the Eco Assist system that shows a growing tree, reflecting the success of the driver in achieving a sustainable driving manner (Fig. 7.3 Right). Nowadays, many companies offer coaching systems that provide suggestions and rewards for sustainable driving. Persuasive technology has also been applied to counter risky driving. An insurance company enabled young drivers to install a dedicated device in their car by which information could be collected about their driving behaviour. Fast acceleration and high speed in curves were seen as signals of a risky driving style. Through calm driving, young drivers could get a discount of their insurance fee.

However, not all drivers may be equally sensitive to the same persuasive strategy, as there is evidence that people may differ as to the persuasive strategy they are sensitive to. In fact, if a wrong persuasive strategy is applied in a system that people cannot turn off, the system may invoke resistance, or even the opposite behaviour (reactance). In the context of automotive, some research efforts have been made to develop such more personalised persuasion systems, but the results so far are inconclusive, for two reasons. In the first place, persuasive strategies that have been shown to be effective in other domains, for instance, the persuasive strategy of scarcity—(cf. "only two rooms left!" in hotel room booking systems) may not be easily translated to the automotive domain; possibly, persuasive strategies may have to be devised specifically for the automotive domain. In the second place, it is not yet clear how to determine which factors determine which persuasive strategy would work best for a particular person, and how to measure such factors.

Finally, gamification approaches usually imply rewards such as fun and excitement, which may not be long-lasting. Likewise, systems offering monetary rewards raise the question of what effective approaches to attitude and behavioural change are. While extrinsic rewards such as money are good for behavioural change, usually they are bad for attitude change. They are effective only as long as the extrinsic reward remains present, and once they are taken away, the driver may fall back into the old behaviour again. Even so, persuasive technology offers an interesting direction for attitude and behavioural change.

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