Behavioural adaptations to new driver support systems
Some critical issues

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Abstract This paper deals with the crucial issue of behavioural adaptation of drivers with respect to (new) driving support systems. In particular, it discusses the theoretical background and the activities and field studies that are planned within the EU-FWP 6 (Framework Programme) Integrated Project AIDE (Adaptive Integrated Driver-vehicle Interface) for identifying parameters and variables to be considered in models of driver behaviour, in order to account for long-term behavioural adaptation.

Keywords: Driving behaviour, Behavioural adaptation, New driver support systems, Traffic safety.

1 Introduction

Over the past 15 years major technological changes have taken place in the field of automobile driving. Many Research and Development programmes (in Europe, USA and Japan) have been devoted to the design and assessment of new driver support systems (for route planning, obstacle detection, car-following situations, speed control, and so on).

The development of these new systems raises crucial questions at a technical level as well as in terms of their consequences on driver activity (for a general overview, see [1], [2]). Some of these questions deal in particular with the conditions of use of these new systems, their effects on driver behaviour and strategies, and their impact on the functioning of the traffic system (traffic, safety).

Numerous processes may in fact come into play between the introduction of a technological innovation, its “adoption” by drivers, its “translation” into behaviour (whether “safe” or “risky”) and its longer-term consequences on the functioning of the traffic system [3].

These processes must therefore be thoroughly investigated, in particular those accounting for drivers interactions with the driving environment.

2 Behavioural Changes

These new systems will mediate drivers’ interactions with their driving environment (vehicle, road infrastructure, other road users) by creating new sources of information and/or offering new modes of action regulation.

They will thus alter the conditions in which the driving task is currently performed and, as a result, changes in drivers activity can be expected. Those changes may occur:

- Within the very activity of “assisted” drivers (in terms of divided attention between the new internal sources of information and direct monitoring of the road environment, changes of driving strategies, delegation of control to the driving support system, ...);
- Within the interactions between “assisted” drivers and other road users (effect on the behaviour of other road users, “readability” of assisted drivers’ behaviour for other drivers, and so on); or
- and, as a result those changes may have an impact at the general level of traffic conditions (speed, stability of traffic flow, and so on).

It is then important to specify the nature, direction and extent of the changes likely to occur at these different levels, since these changes will determine the ultimate impact on road safety [4], [5].

3 Behavioural adaptation in road safety research

In road safety research, the term “behavioural adaptation” is mainly used to signal unexpected or unanticipated behavioural changes that appear in response to the introduction of a change in the traffic system and which may (more or less) jeopardise its expected safety benefits. Thus, the emphasis is primarily put on the
negative aspects of the phenomenon. Behavioural adaptation may be an immediate response to the change introduced in the traffic system or may only appear after a long time period.

Although behavioural adaptation is a widely acknowledged phenomenon, the factors likely to explain it and the processes underlying its occurrence (in time and space) and are not clearly established.

Various driver models, such as models of drivers’ risk control, are often referred to when studying behavioural adaptation (for a discussion of these models see for instance [6], [7]). These models emphasise the role of several processes (cognitive and motivational) which may induce the occurrence of a behavioural response and influence its direction and magnitude. In line with these models, several variables have been examined, such as the drivers’ perception of the change introduced in the traffic system (does the change directly influence the way the driving task is performed, does the change alter the drivers’ subjective safety?), the degree of freedom that the change allows drivers (is there any opportunity for drivers to change their behaviour?), the presence of competitive motives for changing behaviour, and so on [5].

As mentioned above, most debates and research works have been devoted to an analysis of the negative aspects of behavioural changes.

When analysing the impact of new support systems, we choose to adopt a larger (and rather more classical in psychological terms) definition of adaptation, considering that the drivers’ responses can be either positive, neutral or negative [4] and that the magnitude and direction of a given behavioural response can evolve over time as the driver becomes more familiar with systems.

Adopting such a definition means that the scope of our investigation will incorporate more potentially relevant behavioural changes associated with the use of the support systems and enable us to find out whether initially positive changes become negative, and initially negative changes positive, over time.

4 Studying Behavioural adaptation

The changes associated with the use of these new support systems and their acceptance by drivers will depend on:

- the types of task they are designed to support, (navigational, guidance or control tasks, [8])
- and on their functions and the type of mediation they provide ("description" as regards the state of the environment, "prescription" as regards the regulating action to take; " back-up " in the event of driver failure or his deliberate delegation).

Up to now, most support systems are dedicated to specific driving tasks. Their competence is by definition limited to the area of that task. The mediation offered is thus only partial, the driver’s direct control over the road environment is always necessary and he remains responsible for the overall management of his journey. Therefore, studying the integration of these new systems in the overall driving activity is essential.

Many research studies have been carried out, focusing on the impact of various individual support systems such as Collision Avoidance System, Speed Limiters or Adaptive Cruise Control, either in the “controlled” context of driving simulator and/or in the complexity of real driving situations.

Most of these research studies have been short or medium term studies and “the effects of the support systems on traffic safety and driver behaviour are still uncertain in many respects” [9].

Nevertheless some critical issues have already been identified. They are briefly described and discussed below.

4.1 The diversity of behavioural changes

The first critical issue encountered when examining the impact of a given support system concerns to the diversity of the behavioural changes observed as well as the magnitude and direction of these changes.

For instance, the main behavioural changes observed when studying the impact of an Adaptive Cruise Control are changes in speed, in the safety margins adopted in car-following situations, and in the lateral control of the vehicle, as well as changes in lane occupancy and in the frequency of lane change manoeuvres [10], [11], [12], [13].

Furthermore, the results obtained are sometimes contradictory: in some studies, speed increases when using ACC whereas in others this is not the case; the same result is observed for the frequency of unsafe safety margins adopted when using ACC. Sometimes the results are similar, as in the case of the lane occupancy.

The diversity of the results obtained raises questions about the methods used, the type and number of variables selected for assessing the impact of the system, and finally the (implicit or explicit) models governing their choice.

When comparing these results, particular attention should be paid to these methodological issues. The context in which the studies have been carried out (driving simulator, tracks or real driving situations) should be specified as well as the various scenarios or driving situations in which the behavioural changes have been identified. In the same way, the duration of exposure to assisted driving should be taken into account. The
This kind of analysis is particularly relevant if we consider that the situational context plays an important role in the behavioural changes observed when driving with a support system.

4.2 The importance of the situational context and the collective dimension of driving

Many systems are designed to support drivers in maintaining some safety thresholds or ensuring compliance with some formal driving rules (such as maintaining safe time headways in car-following situations or adhering to legal speed limits), independently of the characteristics of the situation and the task being performed or planned, which determine the driver’s current regulating actions. Several studies show that drivers’ use and acceptance of these systems closely depends on the way they integrated these formal rules in their driving and the tolerance they deem admissible, according to the situational context (infrastructure and or traffic related) and the task to be carried out.

These studies reveal the influence of the overall traffic conditions and of the characteristics of the road infrastructure on the use of the support systems (decision to engage the system, for instance [13]) and on the magnitude of the behavioural changes observed when using them (for instance, increase of safety margins before overtaking only in light traffic conditions [11]).

Drivers’ use and acceptance of the assistance provided also depend on its impact on the way they usually manage their interactions with other drivers (on the basis of more or less informal rules or behavioural norms). In many interaction situations, such as driving in dense or unstable traffic conditions, drivers are reluctant to use the systems when doing so would require a significant deviation from their usual strategies. Furthermore, they are concerned about the way other drivers might interpret their own behaviour. Some critical reactions of other drivers (close-following behind, cutting-in manoeuvres, flashing headlights....) are perceived as a negative feedback and often lead them to give up the use of the support system or to ignore its recommendation.

To sum up, these studies highlight the circumstantial requirements of driving assistance according to the dynamics of various environmental conditions and to the drivers’ motives, objectives and intentions in these conditions.

4.3 The differential impact of a given support system

Another critical issue for studying behavioural adaptation is related to the potential differential impact of the support systems. Many individual characteristics may be considered relevant for dealing with this issue, such as the driver’s age and gender, degree of experience, ... but also personality traits such as sensation seeking, and so on.

The choice of a set of individual characteristics mainly depends on the objectives of the research study and the process under investigation.

Recently, the concept of “driving style” has received particular attention when assessing the differential impact of driver support systems. It is not in the scope of this paper to discuss the various dimensions characterising the driving style nor the different behavioural indicators used to render this variable operational.

Basically, the driving style is described as a relatively stable characteristic of the driver, which typifies his/her personal way of driving, the way he/she chooses to drive (for instance, the level of speed or the safety margins more frequently adopted, the general level of attention devoted to the driving task and so on).

Several studies have take into account this variable when studying the impact of an ACC system, either by design (the participants were selected on the basis of a questionnaire focusing on two main dimensions of driving style, speed and focus [12]) or a posteriori on the basis of some manifest behaviour patterns (such as the driver’s propensity to change lane frequently on the motorway [8] or the driver’s tendency to drive faster or slower than the surrounding traffic, to adopt short time headway in car-following situations, ...[11], [13]).

The results suggest that the various dimensions of the driving style taken into account in these studies play an important role for explaining the behavioural adaptations observed.

For instance, some behavioural changes associated with the use of ACC, such as a reduction in the number of lane change manoeuvres and a higher rate of left-lane occupancy, are primarily observed within the group of laterally “mobile” drivers (drivers who tend to change lane frequently). Driving styles, as we will see below, also play an important role in terms of frequency of use of the ACC system.

4.4 The diversity of drivers’ interaction modes with a support system

As far as we know, very few studies have examined in detail the way drivers interact with a new support system. However, such an analysis should provide useful information for understanding how drivers share and learn to share the control of their driving with a new support system.
The results of some in-depth studies of drivers’ interactions with an ACC system (Adaptive Cruise Control) [13], [14] emphasize the great diversity of interaction modes used by drivers:

- in terms of ACC engagement (mainly depending on the type of road, the speed level and the traffic density) as well as in terms of the overall duration of ACC engagement (associated with the age of the drivers and with their “driving styles”);

- in terms of the drivers’ use of commands for setting and adjusting the set speed values and in terms of driver’s “taking over actions” (direct intervention on the accelerator or the brake). Once again, The situational context as well as the characteristics of the drivers (their “driving style”) seem to play a crucial role in the way drivers interact with the driving support system.

We should keep in mind that these results were obtained during short and medium exposure to ACC driving. Part of the observed diversity may reflect the fact that drivers are still exploring the various modes available for interacting with the system. On the other hand, this diversity may also reflect the fact that drivers have acquired enough experience with ACC to be able to diversify their interaction modes, according to the various situational contexts encountered during their journeys.

Longitudinal studies are needed in order to explore these alternative hypotheses.

4.5 Some methodological issues

An examination of the various studies on behavioural adaptation highlight some methodological questions for assessing the impact of new driver support systems.

Studying the integration of a new aid into driving activity and identifying behavioural changes entails:

- Taking account of the essential dimensions of the road environment in which that activity takes place (nature of the interactions at work, regulatory, structural and dynamic constraints, etc.). This reference to the context [15] is particularly important in view of the diversity and variability of the road situations that drivers may encounter during a journey.

- Choosing functional units of analysis making it possible to examine not only the aid’s impact on the performance of the specific task to which it is dedicated (compliance with safety margins or speed limits, for instance), but also its compatibility with the performance of other driving tasks (overtaking manoeuvres, interactions with other users, and so on).

- Selecting the relevant indicators for revealing the changes likely to take place in drivers activity.

Prior analysis of road situations and driver activity provides a useful conceptual and methodological framework for making those choices.

5 The issue of behavioural adaptation in modern vehicle systems: The AIDE project

As mentioned above, most studies of behavioural adaptations to new driver support systems have been short-term studies and focusing mainly on the use of a single support system.

Studying long term behavioural adaptations and developing an integrated management of driver support remains however a necessary and unavoidable step in defining the layout of models of driver behaviour that support the design and development of integrated tools and interfaces.

This issue is one of the major goals of the newly started EU-FWP 6 (Framework Programme) Integrated Project AIDE (Adaptive Integrated Driver-vehicle Interface). In particular, AIDE aims at generating knowledge and methodologies and developing human-machine interface technologies for safe and efficient integration into the driving environment of Advanced Driver Assistance Systems (ADAS) and In-vehicle Information Systems (IVIS), as well as nomad devices.

The planning of the research activity with respect to the issue of behavioural adaptation deals firstly with the problem of the circumstantial and temporal management of the assistance provided by various systems in the driving process.

With respect to the circumstantial conditions that affect processes of behavioural change, the following aspects will be studied:

- The nature and extent of behavioural changes associated with the use of individual driver support systems;

- The conditions in which these changes take place;

- The “reasons” why these changes occur;

- The characteristics of the drivers more likely to present these behavioural changes;
With respect to the temporal factors affecting behavioural adaptation, the variables will be organised according to specific phases for long-term effects. In particular, two main phases will be considered, namely:

- **Learning and appropriation phase**: the driver discovers the system, learns how it operates, identifies the precise limits of its competence and delimits its domains of utility. This learning process is assumed to be crucial for the driver representation of the system, the confidence he/she has (and ought to have) in it and its optimal use. This learning process depends on the way the system is presented to the driver (instruction for use, as well as information provided on-line), the driver level of experience and familiarisation with new technologies.

- **Integration phase**: the driver, through experience using the system in different road situations, reorganises his/her activity by integrating the system in the management of the overall driving task.

This process will lead to the identification of the relevant variables to be used to assess behavioural adaptation effects. The correlation with these variables and adequate taxonomies and classification of road situations and driving tasks (scenarios of dynamic situation) will be devised in order to associate the variables with realistic conditions.

In this way it will be possible to plan and carry out a number of experimental and field evaluations that will enable to develop and consolidate a model of driver behaviour that can act as reference for the design of an adaptive-integrated in vehicle interface supporting the multiple tasks of drivers in modern vehicles.

6 References


