Challenge of Human Factor Influence for Car Safety

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Symposium of Santa Clara on Challenges in Internet and Interdisciplinary Research - SSCCII-2004, Santa Clara, Italy, January 29 – February 1, 2004

Abstract:

Human society needs still more intensive exploitation of all kinds of transportation facilities. This need lasts already several decades and will be much more imperative in future. Mobility is one of most strict requirements for survival, besides the energy and food resources, health care and security.

The requirements on transportation systems concern not only the quantitative and qualitative aspects of transportation activities, but still more also the aspects of their reliability and safety. This concerns not only the transported subjects or goods, but also the environment.

The losses caused by failures of transportation activities reach even now very high level and if not limited by systematic research and preventive activity, will reach already soon quite tremendous level.

However, practically all the contemporary transportation vehicles, trains, ships and planes and also all the transportation systems need for their proper operation the interaction with human beings, which drives them, control them or use them and maintain them.

In spite of the fact significant progress was made in recent years as concerns the transportation systems automation, the fully automatic transportation system in use is still for-seen in the considerably far future.

Analyzing the reliability and safety of transportation, one finds that the activity of human being is the weakest point. The technical reliability of almost all the transportation tools has improved quite a lot in recent years, however the human subject interacting with them has not changed too much, as concerns his/her reliability and safety of the respective necessary interaction.

Therefore there is a hard necessity to improve it and the possibilities how to increase it will stay still more in the focus of our interest.

In this contribution the overview of related problems is made, the challenges for further research and development in this area are discussed and the outline of the

vision of with respect to human interaction reliability optimized transportation systems is presented.

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1. Introduction

The problems of non-satisfactory level of interaction between human subject and artificial system exist in almost all areas of human activity. Here we shall concentrate mainly on the case of the reliability of the interaction of the driver with car.

This is of course a very important area, while the volume and density of road transport rises every day and the number of road accidents reaches tremendous level. According the data from EU (presented e.g. on the conference of ERTICO, Prague, 2002), on European roads more than 42000 people per year are killed, which is estimated to losses of about 165 billions Euro. To this figure one has to add the price of non-mortal accidents, which are cheaper in average, of course, but much more frequent. Suppose that their total reaches about the same level.

This concerns the so-called primary losses. The secondary losses, involving the necessary medical care, social expenses, losses of work capacity etc. are hard to determine by statistics and the estimations differ. However as reasonable estimation the equality to primary losses can be taken. Very roughly speaking, one can therefore estimate the losses caused by accidents on EU roads and due the subsequent expenses to about 600 billions Euro per year. Without intensive and systematic preventive activity, this figure has the tendency to increase from year to year.

Similar situation is also as concerns other areas of transportation activities. The total figure of all these losses one can hardy estimate, but in any case this is extremely high.

Because of non complete statistics it is not easy to estimate, which part of this is caused by fatigue of the human subjects, as the methodology is not internationally standardized yet and differs significantly state to state. In literature, the values from 15 to 50% can be found. Nevertheless one can take the figure of 20% of the total volume of accidents being caused by the human subjects fatigue as very realistic. If one takes into account also the price, which we all have to pay for non-mortal accidents, we can speak of about 120 billion Euro per year lost due the decrease of attention of drivers below certain acceptable level. The losses in the Czech Republic are estimated to be quite proportional.

2. Motivation

The need to minimize these losses is the dominant motivation for activity in this area.

Let us restrict here to the car-driver and vehicle interaction.

The progress in this respect could be reached by combination of the following 5 main approaches, which needs an *very interdisciplinary* approach:

a) Improvement of the training the drivers with respect to their higher resistance to disturbing factors causing decrease of their attention,
b) Improvement of the interior of the car cockpit with respect to minimizing the influence of disturbing factors causing the decrease of drivers attention and enrichment of the car equipments by new active and passive tools improving the driving safety,
c) Development of micro-sleep warning systems and their installation in car cockpit
d) Improvement of the traffic control systems with respect to wide scale detection of risky and aggressive driving and of its punishment,
e) Investigation of the influence of various drugs (including alcohol, nicotine etc) on human subject driving activity and development of new pharmatics improving the human attention

None of these 5 approaches is universal, however also no of them can be neglected.

As concerns the *drivers training*, much can be reached by the use of traditional methods, especially if they are completed by the systematic use of advanced driving simulators. However, the progressive training methods based on the use of

simulators equipped by *bio-feedback tools* (see Fig.1), if the training is carried out in satisfactory number of repetitions and being controlled by skilled neurologist or psychologist can lead to significantly improved resistance against both the fatigue and number of disturbing factors influencing the driver during his/her driving activity. Such enhanced state of the particular person resistance against fatigue can last considerably long, probably up to few years. In this period, the threat that his/her attention level falls down below acceptable level when driving is much less.

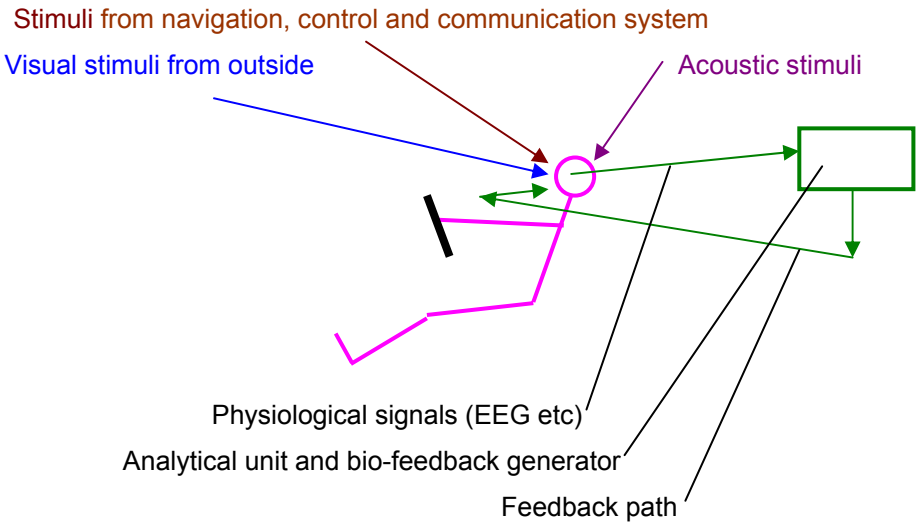

Fig. 1: The basic principle of bio-feedback training

The education of new drivers (especially professionals) represents a very important part of transportation-oriented industry. To reach the main goal of its activity, i.e. the training a mass of people for to be able to operate as good drivers, with high efficiency and reliability is of course a very strong motivation, which projects also in significant economic gain.

As concerns the *car interior*, much can be done to optimize the shape, position and kind of use of the tools for driving control – i.e. the driving wheel, pedals, gear handle, instruments on the cockpit panel etc. This optimization has to be provided not only with respect to driver convenience and comfort, however before all to reliability and safety of his/her interaction with the system of car, especially with its driving control. One of most important aspect in this respect represents the optimization of the on-board mobile phone to minimize the negative influence of its use on driver attention. The development and design of so optimized cockpit stay in the focus of interest of various leading car manufacturers.

Much can be done also as concerns new kinds of electronic and information on-board tools, which will have positive influence on driving safety. Among them are e.g. the car radars, detecting not only the existence of nearest other car in the front and on the rear, but also controlling automatically the safe distance from it. Also the information systems, predicting on-board and in to driver acceptable form the most important weather parameters (temperature, wind, humidity, rain, fog, ice-on-road etc) along the expected car travel trajectory for prediction horizon of 1-2 hours can help very much.

In recent years there were realized several attempts how to design the on-board applicable system, which can automatically warn the driver against of his/her serious attention decrease and the advent of micro-sleep. Till now, however, no of them does reach the maturity for practical application. Those, which are based on the so called secondary markers, face the problems with low specificity and eventually long time delay between the real decrease of attention and significant change of respective parameter (in certain cases this delay can be several tens of seconds or few minutes). Those approaches, which deal with analysis of electromagnetic radiation from the driver brain does not suffer from such problems, however they are not easy for practical application especially because of technical problems with measurement of very weak electromagnetic field on the driver head in moving car and of the very high individuality of each driver brain electromagnetic pattern. Nevertheless, there exist a very high motivation for development of such warning tool.

All the above mentioned approaches how to diminish the losses in traffic accidents fail, if there is no good will of the driver to use the respective warning tools and to follow the respective recommendations. Because the drivers community consist unfortunately not only of the good willing people, but also of individuals of non-tolerant, careless, indolent, risky or aggressive nature, the *system of general supervision of drivers behavior* and of the respective punishment of eventual aberrances from given standards seems to be quite necessary. Of course, the development and introduction into practical application of such system represents a very complicated problem, not only from the technical, but also from legal and juristic point of view. Nevertheless, the motivation to reach this goal is also very strong.

The last mentioned approaches is based on recent developments, reached in the field of neuro-pharmacology as concerns the drugs, increasing the level of human

subject attention, his/her speed of reaction and the probability of correct reactions, even in high physical and psychical load. Though much more research has to be done in this area, one can expect that in not to far future we shall know much more about possibilities how to use such medicaments, like methylphenidate (Ritalin) e.g. to prevent the possibility of fatal decrease of human subject attention and not causing a set of negative side-effects for particular person health. Also the possibilities of external attention stimulation (e.g. by suitable modulated magnetic or electric fields) represent a serious challenge, which needs intensive research.

3. The Structure of Stimuli, Interacting with Car-driver

The main kinds of stimuli, which affect the driver behavior when driving car are sketched schematically in Fig. 2.

One can divide them into two main groups:

the external stimuli,

the internal stimuli.

Another division can recognize:

the natural stimuli,

the artificial stimuli.

Among the *external stimuli*, the visual one sare evidently of the main importance. Here one has to distinguish the visual stimuli, describing the position and move of the car on the road, the stimuli informing the driver about external situation, road signs and other traffic and the stimuli informing him/her about the car control, navigation and communication equipments. They differ nor only in shape, size, color and intensity, but also varies in time of appearance, length of existence and necessity of either periodic or permanent observation.

Beside the visual stimuli, also the acoustic signals play an interesting role. These can be of the warning kind (from outside traffic, or from the own car – skilled driver permanently listen the noise of his/her own car), or of the disturbing nature (noise, communication with the car crew or listening radio – here much more research has to be done for to know, which kind of radio programs help and which destroy the driver attention).

Another important group of external stimuli is generated by the human subject mechanical sensors. The driver is exposed to the influence complicated mechanical

forces, consisting of vibration components component of accelerations and decelerations and centrifugal components. This is of especial importance for skilled drivers, which very often analyze the driving situation out of their will just by these stimuli. On the other hand, the absence of such stimuli in simulator can lead to so called simulator sickness, which, especially for skilled divers can have the form of nausea. The furnishing of the simulator by a set for such stimuli simulation belongs to very expensive and laborious problems.

Almost all drivers operate the car having their hands on the driving wheel. The system driving wheel – drivers hands represent a very complicated and sensitive interface, where interact the mechanical stimuli coming from the move of the car on the road with the stimuli coming from drivers brain through his/her motoric system. The very careful analysis of hand reflections promises to be a good source of information about the level of the driver attention and his/her actual ability for safe driving.

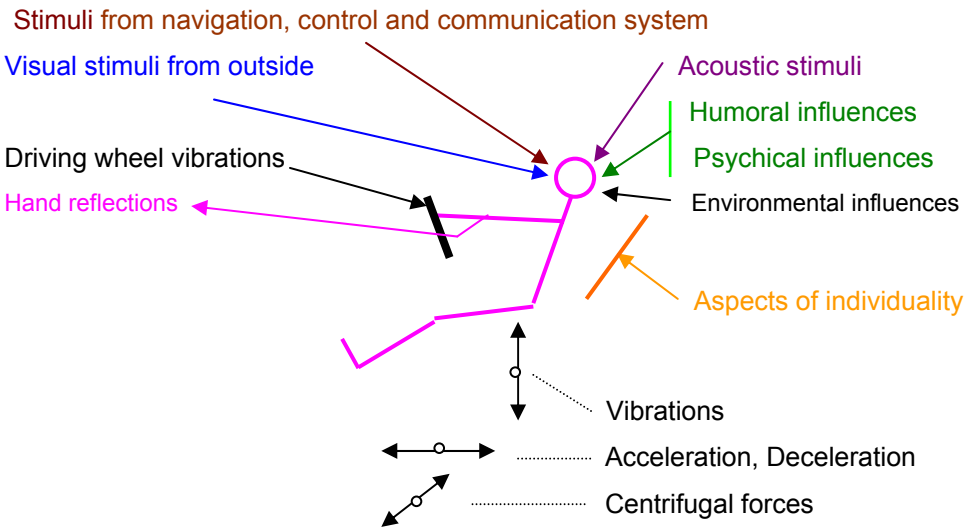

Fig. 2: The main kinds of stimuli to which the car-driver has to face.

Internal stimuli come before all from the particular driver general physical and psychical conditions and of course also from the presence of eventual drug load of his/her organism. As concerns the drugs, the alcohol and nicotine load appears most frequently. While the negative influence of alcohol on particular driver ability for reliable and safe driving is widely known and in many countries respected by various legal limits for acceptable percent of alcohol in drivers blood, considerably few is

known about influence of nicotine (and other drugs, including caffeine). This concerns especially their long lasting and combined exposition.

Here also the factor of driver individuality must be taken into account.

All the above mentioned kinds of stimuli can be taken as the natural. However, besides these, the driver can be exposed also to artificial stimuli, like the external physical fields or drugs influence, which can have either the positive, but also negative influence on his/her level of attention and ability for safe control of the moving car. As it was already mentioned these need very intensive and systematic research, both from the preventive and also from the improving aspects.

All such investigation needs to be done on considerably large number of experimental persons (probands), especially because of very high level of human subject and namely his/her brain individuality. Here the development of the international data-base for neuroinformatics, organized in the range of the respective Global Science Forum OECD will be of very high significance.

4. Reliability Aspects

As was already mentioned elsewhere (see [3,4] e.g.), the ability for reliable and safe driving can be represented by some point in the multi-dimensional space {X} of the N parameters x_i representing the drivers attention level. In general various kinds of parameters x_i can be taken into account. However, because the determination of their values is very often loaded with considerably high level of fuzziness, the restriction of the number N to small values is recommendable. For practical investigations, one deals therefore before all with two main parameters, representing the level of attention, i.e. the driver reaction time RT and the probability P_{corr} of his/her correct or wrong response to certain external stimulus.

In the plane (RT, P_{corr}), the regions of acceptable attention are then restricted inside the gray shaded area, shown schematically in Fig. 3 (values of RF below 200 msec does not appear in practice, the RT above 1000 msec represent the fall into micro-sleep).

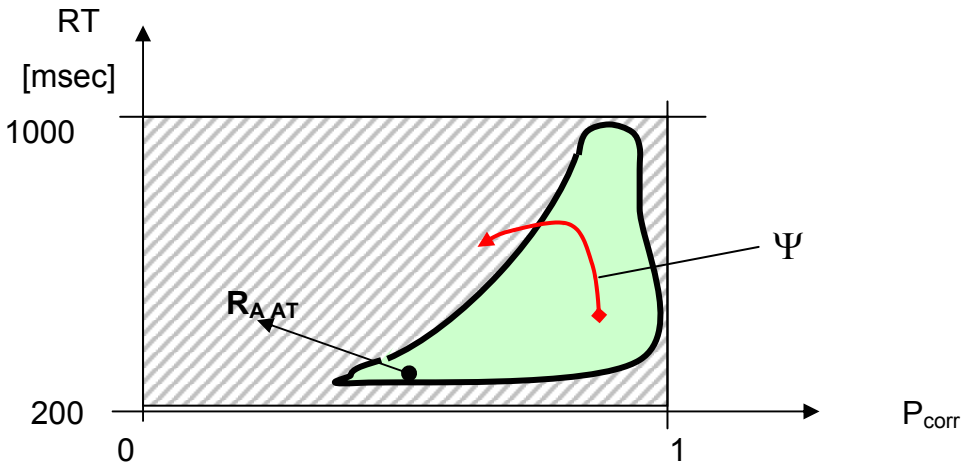

Fig. 3: The region of acceptable drivers level of attention and the respective life curve Ψ.

However, the investigation of the boundaries of $R_{A\ AT}$, even in such two-dimensional space represents a very laborious and complicated problem, especially because the various types of car, road, driving situation and especially also due the above mentioned drivers individuality has to be taken into account. Of course, often the boundaries of $R_{A\ AT}$ or some their parts have often more or less fuzzy character.

In the course of driving, the point X = {RT,P_{corr}}, representing the actual level of particular driver attention moves in the space {RT, P_{corr}}. It follows some curve, which in analogy to the technical system reliability theory can be called the "life curve" Ψ. This can be parametrized by the values of various independent variables, namely by time. If Ψ remains inside $R_{A\ AT}$, the driver is able to drive considerably reliable and safe. If it approaches the boundaries of $R_{A\ AT}$ or if it brakes it the situation becomes dangerous.

5. Problems and Challenges

The motivations mentioned in the previous chapter stands before us some important actual problems, which also represent challenges for further research.

We shall try here to discuss some of them:

a) The creation of satisfactory large data-base of EEG data, measured on special selected set of human subject – probands, simulating the

sample of drivers community. The respective laboratory measurements has to be made in a considerably dense grid of electrodes (at least 29) located according the wide accepted international standard (e.g. 10/20) during the appropriate long observation session (probably 30 to 45 minutes). During this time the subject controls the car movement on simulator, observing some standard scene. In this artificial scene the rural and urban roads has to be simulated, both including the points, in which the probands reaction time and correctness of his/her reaction will be tested. While the filling out of such base – the Micro-Sleep Base MSB, which proposal was already made (see [1,2]), is out of possibilities of one single laboratory, the necessity of coordinated international cooperation of several laboratories in different countries and different parts of world exist. These laboratories has to share a common methodology for to be able to produce compatible results, of course.

b) Mining of relevant hidden interrelations and knowledge from the sub a) created data-base.

c) The development of new, more selective and specific methods for analysis of quasi-periodic and quasi-stationary time series typical for EEG signals, which will be taken as part of the common recommended methodology (see [5] e.g.).

d) The development of suitable electrodes for EEG recording applicable in moving car, not (or minimally) disturbing the driver. The application must be possible without any auxiliary help. Probably (as both recent experimental data and theoretical consideration show), only two pairs of electrodes located in the area of drivers head behind his/her ears will be satisfactory. The transmission of measured signals to the analytical equipment, installed in car panel must be wireless and satisfactory reliable.

e) The investigation of possibilities of contact-less measurements of electromagnetic radiation (either as electric potentials or eventually magnetic fields) emitted by human brain, which can be applied in moving car. In these investigations a special interest has to be given

to the eventual possibility to use the specific parts of electromagnetic spectrum, for which the scalp and head are more transparent.

f) The investigation of the influences of special modulated and located either electric or magnetic fields on the drivers level of attention.

g) The investigation of influence of the set of external and internal disturbing factors, causing the diminishing of driver attention. Among such factors, the influence should be investigated both individual and in combination, such has to be included as:

Temperature,
Humidity,
Air pressure,
Illumination,
Noise,
Communication (including mobile phones),
Alcohol,
Drugs, including nicotine,
Mental state diseases.

A special importance has to be given to the influence of mobile calls. Here also the analysis of the density and kind of use among drivers in different regions and time of year has to be done.

h) The investigation of possibilities to detect the driver fall into relaxant, somnolent or eventually micro-sleep stage by the use of suitable combination of some secondary factors, like the eye movement, face analysis etc., probably calibrated by the analysis of EEG signals (see [3,4] e.g.).

i) The development of special designed mobile set, which could be permanently inserted in car as a fixed part of its cockpit, designed to minimize the disturbing of drivers attention when driving.

j) The development of a set of recommendations for optimizing the car cockpit with respect to minimizing the subsequent degradation of driver attention. Here the special interest has to be given to the interaction of driver with navigation tools, radio (eventually TV) and communication systems (e-mail, Internet etc).

k) The development of auxiliary electronic and information tools, which can improve the car driving safety, like the car front and rear radars, on-board weather prediction systems etc.

l) The development of warning system, which can give to the driver satisfactorily in advance (at least few tens of seconds) the information, that his/her attention level is falling down near the boundaries of acceptability. The eventual warning has to be realized in the form, minimizing the possibility, that the somnolent driver either neglect it or on the other hand react panicky. Probably the artificial voice will be a good selection, combined with the set of other subsequently graduated warning signals, when the warned subject will not react adequate. As the last tool the automatic stopping of car movement has to be used.

m) The development of the satisfactorily reliable and safe classifiers and predictors of driver attention falling down, which will probably be highly individual for particular person. Investigation of the time (or other independent influences) for which they can be used (the time, or range of other independent influences, for which the image of the selected warning parameters of drivers attention – dominantly the EEG – is not significantly changed). Investigation of the possibilities to find among these individual classifiers and predictors some typical groups.

n) The investigation of the regions of minimal acceptable level of attention for different drivers, car and driving situation. The boundaries or their suitable approximations of these regions of acceptable attention has to be inserted in the driver attention analytic and warning system installed in the car cockpit together with the individual attention decrease predictors of the particular driver.

o) The development of the system, which allows to automatically investigate the actual drivers behavior on the selected dangerous parts of the road net, to detect the respective traffic situation, in which they eventually cross the limits of reasonable and safe driving and to start their necessary warning and subsequent punishment.

p) Development of the improved education and training system for drivers, which (e.g. on the base of advanced biofeedback) can enhance their

resistance to fatigue and also diminish their eventual tendency to the risky and aggressive driving.

r) The investigation of drugs, supporting and improving the level of human being attention while driving a car.

6. Vision

The operation of driver in moving car is an example of very complicated interaction between several very heterogeneous systems. Some of them are artificial, i.e. the car, the road (tunnel, bridge), the traffic control system, some are of real nature (driver, passengers, surrounding community, the controllers of traffic control system, police, justice). All of them interact in very complicated manner, which we at present are not able to analyze with necessary accuracy and reliability.

Even the relative simple interactions, like those between the driver and the moving car, sketched in Fig. 1 are not quite easy to understand.

Evidently, the solution of the above-mentioned challenges represents a very long research and development. Even if after much work some significant results will be reached, one can-not expect, that they will come very fast in practical use, even that there is evident strong need for it. This appears just because of natural conservatives of our human society.

Nevertheless, we can have the vision that subsequently we shall reach also some success in this respect and that we can so contribute to minimization of those tremendous danger and losses, which we daily see on our roads.

As a good starting point for this we can see the acceptance of the long time international program “Neuroinformatics” in the range of Global Science Forum OECD, in which we expect to start the development in respective international cooperation the development of the above-mentioned Micro-Sleep Base – as one of the first necessary steps. The interest of some significant car manufacturers, namely the Škoda-Auto Co., and the VW Co. to use the results of the research in this area for improvement of the safety of their cars is extremely valuable, of course. We can hope also, that also some significant insurance companies will recognize the chances, which evidently exist in introduction of the results in the field of human subject – car interaction reliability.

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