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Impact of Human Machine Interface Changes on Human Performance and Safety

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Abstract: To survive, industry must continue to change technology and diversify human-man machine designs to meet the ever changing needs and requirements of the modern market in terms of performance, reliability, safety and contort. As far as the human operator is concerned with this technological evolutions, he is asked to perform more or less a similar task but with a modified HM interface. Like driving a new car, the driving task remains the same but with different tools of communication with the machine and new aiding systems introduced by the new HM interface. These changes on the interface may affect the operator mental representation and may cause operating errors and accidents. Generally, it is very difficult to assess simply by common sense the impact of changes of interface on human performance of complex systems especially in critical or in emergency situations. This study presents an approach to assess the impact of a Driving Aiding System (DAS) on the performance of human driver and safety. The system DAS is a type of lane keeping which acts by firstly alerting the driver by vibrations on the steering wheel when the trajectory of the vehicle approaches the white lines and secondly, by generating a torque on the steering wheel in a way that keep the position of the vehicle between the while lines. The research is sponsored by PROMOTEUS to develop aiding systems to improve road transport safety.

Key words: Aiding system, HM interface, human reliability, safety, performance shaping factors

INTRODUCTION

Industry is in constant evolution by introducing new technologies mainly for economical and social reasons. The economical reasons are increase of productivity and improvement of quality and reliability of products. The social reasons are achievement of better working conditions and higher level of safety for the operators. The changes are implemented in real by the replacement of old machines and tools by new ones which are more powerful, using sophisticated performance aids in order to increase human performance and reliability. However, the new machines are operated by the same operator to perform more or less the same task but with a different H-M Interface (HMI). The HMI are used by the operator to communicate, drive and control the machine in all the possible situations in order do perform the task required. Then, the HMI must be designed in such a way to satisfy operator needs, capacity and skill. The two elements, operator and HMI cannot be separated (Baily, 1982) and any change of HMI may lead to errors. In fact, if changes are made on the interface, the operator would try to adapt his strategies; he establish a new mental representation of the system and modify his operation modes in a way as to maintain the same level of performance and safety. In case of inadequate mental model, human performance would be reduced and may affect global safety of the system. The question is, can we predict the impact due to any changes in HMI on human performance?

The state of the art is that large number of models is proposed to describe and predict human performance. Most of them are hypothetical and difficult to apply in practice.

This study presents an approach to assess of the impact due to changes in human machine interface on the performance of human operator.

MODEL OF HUMAN PERFORMANCE

Human performance may be defined as the outcome of a task performed to achieve a goal with a given standard in a given context (Baily, 1982). The standard defines the acceptable tolerance interval of the outcome. Task outcome which does not satisfy the standard is considered as human error. Human errors are events which must be prevented from occurring because they may initiate incidents or accidents which may put at risk human lives, systems and environment. That is why, human errors and their causes and consequences must be taken into account in all the steps of conception, construction an operation of complex systems.

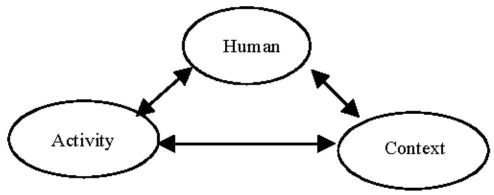

Fig. 1: Human-machine model (Baily, 1982)

Many, human factors experts recognize that human machine interaction is very complex and propose number of empirical qualitative and quantitative models (Balbir, 1986). The common point between these models is that human performance can be analyzed, in most, if not all of cases, with the model described in Fig. 1.

This means that human performance can be influenced not only by human internal factors but also by factors related to the task, the context and theirs interactions. The element task includes procedures and rules, interfaces, aiding systems and training. The element context includes physical environment (ex: Noise, visibility, temperature, etc.) and social environment (ex: Other operators, isolation, work timing, etc). SWAIN model gives the central role to human whose performance can be influenced in a positive or negative way by factors called PSF (Performance Shaping Factors) (Swain and Guttman, 1983). Although, most PSF factors are interdependent, they can be divided in three classes with respect to the human element. Internal PSF factors, external PSF factors and stress factors. Stress PSF's may be internal or external factors which are difficult to predict and usually the main cause of operation error in emergency situations. In order to improve human performance we have to monitor all the PSF's related to the Human-task-context system. However, this is impossible to achieve in practice. Most of the PSF's are stochastic, interdependent, nonlinear and incontrollable variables. That is why human action is always performed with a certain amount of uncertainty. The problem remains difficult because of the lack of objective statistics. Bayesian approach is often employed to combine existing data with expert judgements.

HUMAN PERFORMANCE ASSESSMENT

Human performance assessment is an essential step to guide the design of human-machine systems. This will be useful only if the relationships between human, task and context are taken into account. Assessment of human performance may be based on qualitative and quantitative analysis of four main parameters which give the human the responsibility for the performance of the systems (Fig. 1). Human reliability, safety, training and satisfaction of the operator.

Human reliability is defined as the probability of error to perform the prescribed tasks. Task errors, even if they are rare, are due to incapacity of operator to deal with the performance shaping factors of the situation. Human errors can occur in different modes: omission errors, commission errors, delay errors, sequential errors, adding task not prescribed. (Balbir, 1986; and Guttman, 1983).

Safety is defined as the risk associated with task errors. The risk is the probability of a task error times by gravity of consequences (Rasmussen *et al.*, 1987). If the risk is unacceptable with respect to the safety objectives, design of the system must be reconsidered.

Training is the process employed to transfer knowledge and skill of perform a task from one person to another. Here the training time required to build sufficient skills for an acceptable level of human performance is an important factor of human performance. Assessment. The training time can be reduced by using appropriate aiding systems which assists the operator in doings part of the tasks especially those are related to safety.

Human satisfaction should be one of the design objectives of all HMM systems. Operator who is satisfied with his job is more motivated and put on it more and more attention to perform it as well as possible; he and his task form one couple well adapted.

The values and the importance of these quantities vary from one system to another depending on the objectives priorities of the designer. If the designer's objective priority is the reduction of operator errors and the training time, certainly, the task will not be pleasant to the operator and may affect human performance in the long run because the satisfaction criteria is no satisfied. Therefore, the designer is faced with the problem of finding the compromise between these four criteria. The best way is to do this during the design or the testing phases of the system.

Assessment of the human machine performance system may be represented as a black box with Performance shaping factors as input variables and the observed response in terms of human reliability, safety, time of training and operator satisfaction as output (Fig. 2). In real systems, the number of input variables is very importance and diverse in nature; there variables which discrete, other are continuous; certain variables are dependant and other independent, even more there are some variables which are observable, others not observables. This implies that it would be very difficult if not impossible to assess the influence of all the PSF's and their interaction on the performance of the system with the classic experimental methods. Simulation is the reasonable approach in terms of cost-effectiveness.

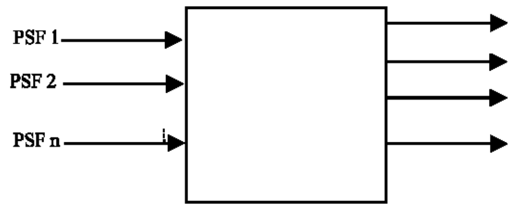

Fig. 2: Human-machine performance system

ASSESSMENT OF DRIVER AIDING SYSTEM (DAS) ON SIMULATOR

Statistics show clearly that the number of driving accidents has attained unacceptable levels. The mains causes are one or the combinations of PSFs related mainly to human, to his activity, to the context or to the interactions of the 3 elements. Relatively small percentage of these causes is related to technical failures. In order de improve safety, European community has setup many research projects such PROMOTHEUS in order to find driver aiding systems which can prevent drivers to make errors, especially those due to non vigilance of inattention. In this project, Renault has developed an aiding system DAS: Driving adding system (in French SAC: système d'aide à la conduite) which can be installed on the existing cars to lane keeping. In fact, 60% of road accidents are caused by non line-keeping which are due to inattention and non vigilance of the drivers. Also, accident analysis show that inattention and vigilance defaults may be caused by many factors which are subjective, cannot be measured or detected early enough before accidents. Some of these cause are, stress, fatigue, distraction by passengers or other things, hypo vigilance, personal problems, alcohol, medicine, etc. Here, DAS system is a aiding to lane keeping system which has two functions activated in sequence to prevent white line crossing accidents.

First, DAS generates a series of mechanical vibrations along the steering wheel to prevent the driver through his hands when the car comes too near of one of the left or the right white lines delimiting the lane and the direction flashing lights are not activated by the driver.

Secondly, DAS apply a torque on the steering wheel in a way to redirect the car inside the lane in case where the driver does not react rapidly till the car come crossing the white lines of the lane.

Introducing DAS system in the car modifies the initial Human-man interface of the vehicle. What would be the impact of this modified interface on the performance of the driver concerning lane keeping by comparison with the vehicle without DAS? More specifically, will DAS system improve safety? Will it be accepted by driver? Will it improve human reliability of drivers? How long does it take to train driver to use this system?

To assess car driver performance when the DAS system is installed on his vehicle in order de reply to the questions above we used two complementary tests: field tests and test on simulator of the model of human performance described in Fig. 1 and 2.

Field and simulation tests: To assess the impact of DAS system on human performance two types of tests haves been carried out: Field tests and simulation tests. These two tests are complementary and helped us to gather significant quantities of field and simulator statistics about driving scenarios without putting ourselves at risk, without costing too much money and time.

The complementarily between the filed test and the simulator tests is important in many aspects. In field tests, it is difficult test all scenarios because some case may be dangerous like testing drivers in hypo vigilance state. It is not easy to repeat events to get statistically significant data and rare events may not be observed at all. On the other hand, tests on simulator are safe, less costly and can simulate reference scenarios in controllable conditions. It is possible de accelerate the occurrence of rare events and repeat scenarios in identical condition as many times as required. The drawback of the simulator is that it does not represent the real world with high fidelity like fired tests. Hence, field tests and simulator tests are both useful and necessary to get acceptable resolution assessment. That is why we decided to carry out the two types of tests in this project of assessing human performance.

In this project we used a large simulator composed of a car fixed on a platform, in front of it is placed a large screen on which is projected an 3D syntheses film of a road. The simulator generates motor vibration but not the acceleration effects and back and lateral glasses.

The scenarios are elaborated considering only the most important Performance Shaping Factors (PSFs):

Internal PSFs: Age, sex, state of the driver.

External PSFs: Added tasks (Rasmussen *et al.*, 1987), road turns (left, right, straight), lane marking (continuous marking, discontinuous marking, interlaced marking); type of road (runaway, two ways road), visibility (good, bad).

Stressing PSFs: Circulation problems (obstacles, urgent situation and circulation fluidity); unexpected technical failures.

Added task technique consists of charging the driver while he his driving to execute some extra tasks like setting his auto radio or simulating technical failures. This would divert driver's attention and create situation of inattention or non vigilance and may lead to non lane keeping errors. After each test, drivers are subject to questionnaire asking them to describe their satisfaction et opinion about the new interface with respect to the existing one.

The sample of forty car drivers including 13 women and 27 men. Eight of them are at least 25 years old, 25 persons are in the range between 25 and 40 years old and 4 are more than 45 years old.

Driving tests have been carried out on simulator and on real roads sometimes with the system DAS in position on and sometimes disconnected. A large amount of data has been collected from the simulator. More than 6000 points of measurements have been done concerning the following variables: car speed, steering wheel torque, car position on the road, state of direction lights. In addition to 55 questionnaires of 50 questions each have been compiled.

The results obtained from the analysis of the data collected are:

Human reliability: lane keeping errors has been estimated to 4% on national road and 8% on runways. The maximal driving speed observed on national roads was 108 km h^{-1} whereas it was 148 km h^{-1} on runaways. Most of the drivers under test think that the new interface with the DAS system has reduced the rate of lane keeping errors.

Safety: In critical or emergency situation where unexpected obstacles appear on the road, such as a road crossing animals, drivers tend to forget to put on direction flash lights before steering rapidly out of the lanes to avoid obstacles. In this situation DAS apply a torque on the steering wheel to force the trajectory in the direction to maintain the car on the middle of the road which certainly lead to collision of the car against obstacles. In a way, in this situation the DAS system is more a hazardous system than it can be an aiding system. Most drivers think that DAS would be safer if the DAS disconnect itself automatically when driver turns rapidly the steering wheel in order to avoid conflict between the driver action and the DAS.

Training time: Most of the drivers subjected to test consider that DAS is simple to use and learn. It require less than tem minutes of training to learn and use it correctly. That is because frequency of the vibrations and the torque on the steering wheel generated by SAD are distinguishable and cannot be confused with other mechanical vibration of the vehicle. The drawback of the interface is that the driver is not informed on DAS is connected or disconnected, it is ON or OFF.

Satisfaction: Drivers tested consider that the system DAS is not comfortable enough because they feel vibrations and torque on the steering wheels even when le vehicle is in the middle of the road. This unexpected response of DAS appears when the white lines are interlaced on the read. Here the software cannot differentiate the true white lines from the false ones.

CONCLUSION

All the time new machines are introduced in the market. Most of them are not new design but a modified or improved technology of the existing ones. With respect to the human operator, it is the HMI which is important because it is the point of communication between him and the machine. The designer of the interface should take into account many aspects related to human to achieve the best coupling between human and the machine. The most important aspects are: human reliability, safety in case of operator errors, training and satisfaction. In this project, assessment of human performance based on these aspects is carried out to find out if the introduction of an aiding system (DAS) in a vehicle is acceptable or not. The results cannot be predictable by common sense because of the complexity of the driving situations. The analysis of data collected from real test and simulator has revealed some hazards in the systems design and gave recommendations to improve safety.

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