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The Target Safety of a Driver's Safety Dependence Comparing with the Target Risk of Risk Compensation

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Abstract

This paper aims to build a Psychological model of over-dependence on driving safety support systems which might reduce general resources of a driver's information processing for safe driving. Some factors which could affect the function are listed and the mechanism of the system is proposed. The well known construct of risk compensation is referred to but is not sufficient to understand the mechanism of over-dependence. Therefore a function of safety-dependence is distinguished from risk compensation. Counterpart construct of "target safety" in safety-dependence to "target risk" in risk compensation is propounded to explain a driver's over-dependence on safety support systems.

Keyword target safety, over-dependence, risk compensation, safety. support system

1. Determinants of Driving Behavior

Figure 1 illustrates three determinants for driving behavior in view of safety. They are "Road Environment Safety (RES)", "Safety Support System (SSS)", and "Driver's Safety Ability (DSA)". In this paper, the relation between SSS and DSA is focused on and the functional model inside DSA is proposed.

1.1. Safety Support System

Various kinds of driving safety support systems have been developed in the research area of ITS. They are categorized as a vehicle itself, cooperative systems between a car

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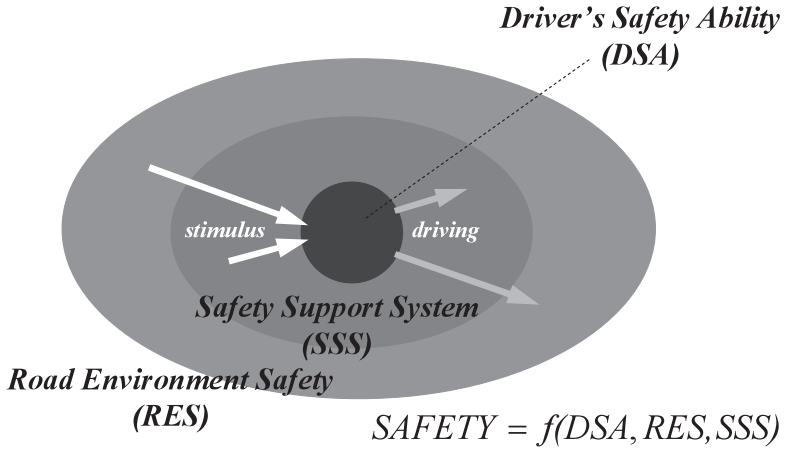

Figure 1. Three determinants of DSA, RES and SSS for driving safety

and the road, and cooperative systems between cars. For example, the ASV (Advanced Safety Vehicle) project in Japan is connected with a car itself, ISA (Intelligent Speed Adaptation) is a European traffic system regarding speeding and DSSS (Driving Safety Support Systems) is a Japanese system which supplements drivers with information of risky traffic situations. Some safety apparatuses in a car have been already implemented and some social experiments have been conducted.

1.2. Driver's Safety Ability

Safe driving is defined as driving a car while avoiding collisions with objects such as pedestrians, bicycles and other cars, etc. maintaining an adequate position against them on a road. Therefore, direct causes of accidents are the error and/or the delay in information processing of a driver. The information processing consists mainly of three phases; perception, judgment, and operation. The potentiality at each phase to avoid the error and the delay means Driver's Safety Ability.

2. Two Functions in Driver's Safety Ability

It could be hypothesized that a driver has several motives during driving. However, two major motives are focused on as they relate driving safety directly as mentioned above.

2.1. Workload Efficient Driving below Target Level of Safety

The first motive is that a driver wants to drive as easily as possible based on economic principle which means to save energy. That is "workload efficiency" which reduces resources necessary for efforts to find potential object collisions and that causes lack of

attention, misperception, and false cognition, *i.e.* the error. However, the driver's subjective impression on a road's condition is safer without referring any risk. That means the recognized level of safety in a given situation is sufficient for the driver's "target level of safety".

2.2. Time Efficient Driving below Target Level of Risk

The second motive is that a driver wants to arrive at his/her goal as shortly as possible. That is "time efficiency" which needs quick operating motion and the typical actions are driving with faster speed and with narrower distance as headway to other vehicles, and they increase the probability of collision, *i.e.* the delay.

On the other hand, the driver does not feel very risky although he recognizes some risks. That means the recognized level of risk in a given situation by the driver is under his "target level of risk".

2.3. Difference between Workload Efficiency and Time Efficiency

The function of workload efficient driving below target safety is essentially different from time efficient driving within target risk by risk homeostasis. The driving manners of workload efficiency originate mainly in the information processing stage of attention and judgment, *i.e.* cognition. Deficiency of object seeking effort is one of the typical strategies to save resources. That increases the probability to cause errors, although saving energy in the motor stage as slow motion, low speed and long headway are not by themselves very risky. Therefore the workload efficiency is considered to be a passive mode of strategy for improving efficiency.

On the other hand, time efficient driving originates mainly in the motor stage as quick motion, speeding, overtaking and narrow headway, etc. Those behaviors cause a lack of time needed to avoid collision. Regarding cognitive process, more energy is needed for a driver to maintain a higher level of vigilance task. Then it is characteristic of the time efficient driving to take in motion strategy for improving efficiency.

3. Effect of SSS on DSA: "Safety Dependence" and "Risk Compensation"

Safety Support System (SSS) could affect function of Driver's Safety Ability (DSA). As described above, one of DSA functions is cognitive process to seek and avoid a colliding object within target safety, and simultaneously try to improve workload efficiency. Correspondent to this motive, some kinds of SSS could imply incentive for a driver to depend on, *i.e.* safety dependence.

The other function of DSA relates motor process rather than cognitive to control driving operation safely, keeping adequate headway distance and speed, etc. within target risk, and simultaneously try to improve time efficiency. Correspondent to this motive, some kinds of SSS could work as incentive for a driver to compensate with, *i.e.* risk

compensation.

3.1. Safety Dependence on SSS

There are some kinds of SSS which are supposed to reduce the mental workload of a driver. For example, ISA (Intelligent Speed Adaptation) works to have a vehicle maintain its speed within the legislated limit, and a driver with this system doesn't need to attend to speed limit signs as the system automatically finds limits data from a digital map of a road section the car is on. DSSS (Driving Safety Support System) is another kind of system which helps a driver to predict possible intersections, traffic signs, pedestrians and other cars, etc., as the system sends information to the driver using various sensors and transmitters on road sides. Consequently the driver's need for workload efficiency is satisfied as he depends on the system for safety as long as the target safety is not surpassed.

3.2. Risk Compensation by SSS

Some kinds of SSS help drivers who want to improve time efficiency. For example, ABS (Anti-lock Braking System) can prevent tires from locking when a driver brakes hard and can maintain handling safely, so he doesn't need to be as careful when reducing speed or to maintain headway distance even when he drives on slippery roads. SRS (supplemental restraint system, Airbag, etc.) protects a driver and passengers from severe damage to the head and chest even in cases of collision with excessive speed. A driver with the system could be less fearful of damage by speeding. Therefore compensatory actions could occur in order to reach the target risk. Consequently a driver's need for time efficiency is satisfied if he compensates the safety effect of the system with risk as long as the target risk is not surpassed.

4. Safety Over-Dependence and Risk Over-Compensation

Regarding both safety dependence and risk compensation, the relationship between workload/time efficiency, objective safety/risk level, subjective safety/risk level, effect of SSS and target safety/risk decides the amount of safety dependence or risk compensation. There are not serious problems as long as the objective safety/risk with the effect of SSS is within the target safety/risk. However, the final objective level of risk could occasionally exceed the target unconsciously, *i.e.* safety over-dependence or risk over-compensation.

4.1. Safety Over-Dependence

Figure 2 illustrates the relationship between workload efficiency, objective and subjective safety level, the effect of SSS and target safety. The perceived effect of SSS could produce some amount of safety dependence. In the case the amount exceeds the

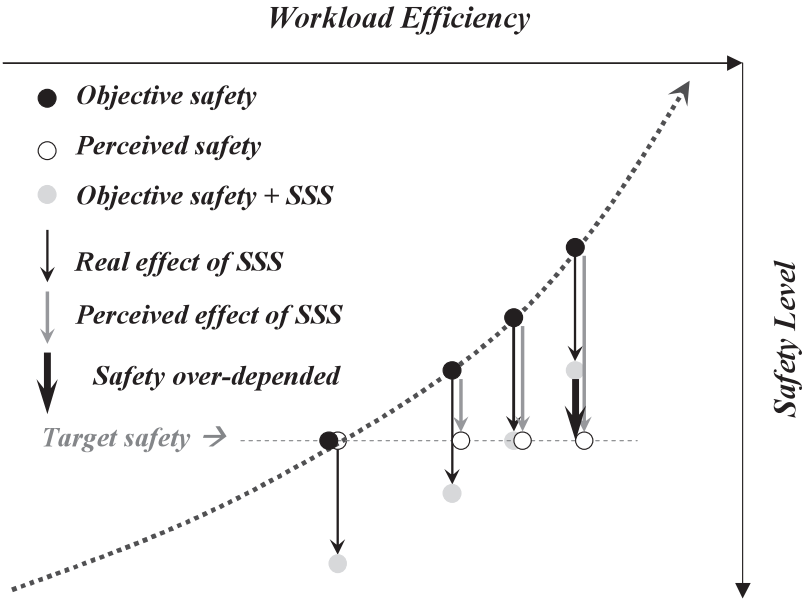

Figure 2. Relationship among workload efficiency, objective and subjective safety level, the effect of SSS and target safety

real effect of SSS, it is considered to be safety over-dependence. Cognitive activity necessary for safe driving even with SSS is further reduced by a driver's over estimation of the effects of SSS than the objective effect. That insufficient level of vigilance, for example, could cause a lapse in attention and/or judgment when the driver encounters a deviate situation which is out of supposed hazards by the SSS.

4.2. Risk Over-Compensation

Figure 3 illustrates the relationship between time efficiency, objective and subjective risk level, the effect of SSS and target risk. The perceived effect of SSS could produce some amount of risk compensation. In the case the amount exceeds the real effect of SSS, it is considered to be risk over-compensation. Driving manners become more active by a driver's over estimation of the effect of SSS than the objective effect.

Quick operation and/or speeding could cause an insufficiency of time to avoid any possible object collision when the driver encounters a deviate situation which is out of the supposed hazards by the SSS.

5. Application of the Model to SSS

Based on the Psychological mechanism model of safety over-dependence and risk over-compensation, some specific characteristics of safety support system such as ITS, ISA or ASV which are necessary for not deriving a driver's over-dependent or over-

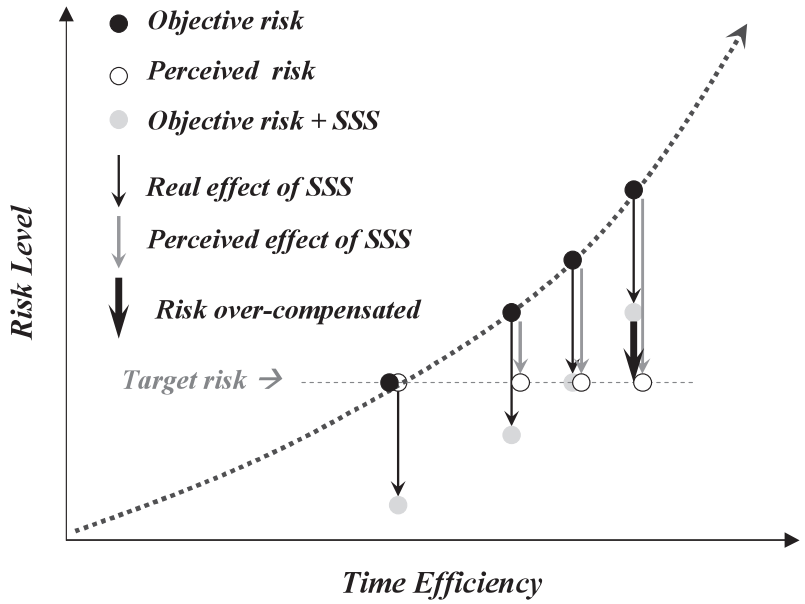

Figure 3. Relationship among time efficiency, objective and subjective risk level, effect of SSS and target risk

compensative behaviors could be possibly obtained. For example, the TTC (time to collision) at which compulsory braking is put on should be adequately set in view of the issue above. The speed level at which the maximum speed limiter works, or the timing an alert is given to a driver should be decided similarly as well. There are some concrete suggestions about the specifications which are expected with SSS.

5.1. Comparison between SSS Recognized and not Recognized

Before some concrete suggestions are listed, a discussion is necessary for them. Figure 4 illustrates the relationship between levels of SSS, DSA and the Safety level compared under conditions of SSS recognized and not recognized. It reveals that there is a large difference regarding outcome of safety over-dependence between the conditions of a driver recognizing the existence of SSS or not. Therefore, the following suggestions about the implementation of SSS is based on this point of view.

5.2. SSS should not be Informed

The first suggestion is that drivers fundamentally should not know the fact of SSS being implemented in their cars. It is not possible for any safety dependence and over-dependence or risk compensation and over-compensation to occur if drivers have no idea about the SSS.

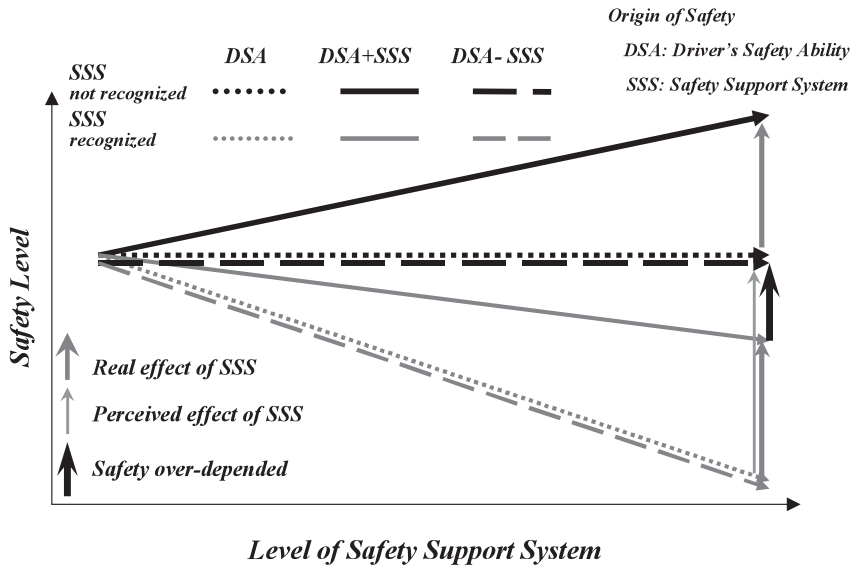

Figure 4. Relationship between levels of SSS, DSA and the Safety level compared under conditions of SSS recognized and not recognized

5.3. Naming of "Safety System" should be Replaced by "Damage Reduction System"

In case drivers are told of implementation of SSS in their cars, the system name should not involve safe image, instead, risky image should be emphasized. For it is supposed that safe image would easily build safety dependence or risk compensation. On the other hand, risky image could suppress dependence or compensation.

5.4. SSS should Work around the Criterion of Hazards

Whether the fact of SSS is implemented in cars is told to drivers or not, and whether SSS forms safe impression in drivers or not, SSS should not work perfectly without having drivers experience any danger at all. For once a driver experiences SSS works to avoid a collision very well, he learns it and safety dependence on, or risk compensation by SSS would be formed. On the other hand, a slight experience of the collision, not a serious one under SSS would give a driver somewhat incomplete reliability on the system and it would be difficult for a driver to be dependent on or risk to be compensated by the system.

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