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The Basis of ”The Self-Explaining Road”

The concept of “the self-explaining road” is used in various contexts associated with demands and objectives to improve traffic conditions and enhancing safety. But exactly what does that mean, and how do we create self-explaining roads?

Explanatory model for road user behaviour
A new report (Ref. 1) describes how we as drivers behave in the traffic and how our behaviour is influenced by road design and traffic environment. The description presents an explanatory model for road user behaviour, the purpose being to establish a practical tool of analysis to be used for the understanding of causes of various problems on the road network. The best basis for finding the solution is to understand the problem. The conclusions of this model form the basis of “the self-explanatory road”.

Nordic human factors guideline
The explanatory model was developed as part of the project *Nordic Human Factors Guideline*. This is a Nordic collaborative project under the Nordic Road Geometry Group. In brief, the project covers road users’ demands to the design and construction of road systems based on existing knowledge about the physical and mental abilities of road users.

The aim of the project has been to collect a fairly comprehensive knowledge on road user behaviour and disseminate such knowledge in a short and manageable form to technicians and planners working in the practical field of improving traffic conditions and road safety.

The work has been carried out by a Nordic research team represented by Lene Herrstedt (Civil Engineer, MSc., Ph.D., Trafitec, Denmark), Gabriel Helmers (Traffic Psychologist, Ph.D., Consultant, Sweden) and Fridulv Sagberg (Traffic Psychologist, Senior Researcher, TOI, Norway).

The project includes four sub-projects (see Figure 1). This article deals with Project II – Development of an explanatory model for road user behaviour

Development of an explanatory model for road user behaviour
In order to design good road and street environments, it is necessary to get a thorough understanding of how we function as road users. Based on existing knowledge about physical and mental abilities of road users, the explanatory model defines some general principles for road user behaviour. These basic characteristics of human behaviour are rooted in general scientific theories. Collecting and summarizing knowledge in more general terms is a necessary step in all theory and knowledge development.

A good explanatory model is a prerequisite for better understanding of road user behaviour.
The development of a practically usable explanatory model is a several-step process. Firstly, some of the basic characteristics of human behaviour are described. This leads to the formulation of general principles for road user behaviour.

These general principles are then used as a tool to analyse and illustrate some very specific problem areas. This is done by using the model to attempt to predict behavioural incidents in traffic. Subsequently, the predictions should be either confirmed or rejected based on empirical studies. If rejected, the model will have to be adjusted. As such, the applicability of the model is tested several times, thus making the model operational. For this purpose, three problem areas have been defined:

- Ghost driving
- Speed choice and conditions for speed adaptation
- Drivers' reading and understanding of road signs and markings

Finally, the practical use of the newly developed explanatory model has been tested. In Part III of the project (see Figure 1), analyses were performed on a number of *problem examples* with the purpose of demonstrating the usability of the explanatory model as a tool for problem analysis and solving of actual traffic problems in practice. The selection of problems is made by Swedish, Danish, and Norwegian road specialists, working with the daily operation and improvement of traffic conditions.

Road user behaviour in an evolutionally perspective
Those species and individuals, who with the least possible effort have achieved the greatest possible benefit, have survived through the ages (Darwin's theory of evolution). Through this "sorting principle" man, with his brain, senses and movement apparatus, is built to function as an effective whole in the environment.

When moving around in traffic we act rationally and effectively based on the principle "greatest possible benefit with the least possible effort". We try to avoid detours by choosing the shortest/fastest possible route with no obstacles.

Even though man is the most developed species on earth, we are born with virtually no skills. We must therefore, as a general rule, acquire everything through learning. We do however, possess certain instincts from the very beginning, i.e. we have an instinctive sense of fear of heights and a natural understanding of the fact that we could hurt ourselves if falling down. In contrast to this, we do not in the same immediate way perceive the speed limits we uphold when driving as particularly dangerous to us. This is something we have to learn.

A new-born child will have to learn what belongs to its own body (i.e. by biting a finger and experiencing the pain) and what does not (i.e. by biting a stick). By acting in our environment we constantly receive feedback on our behaviour and gradually we will lean to understand the features of our environment and its objects. Through such feedback we eventually learn how to achieve the "benefits" and avoid the "dangers" in our environment.

This learning process repeats itself each time we need to acquire new skills. In a traffic related context, we must learn to walk, ride a bike, and drive a car. Once we have learned how to operate a vehicle, we consider this as an almost natural extension of our arms and legs.

During the learning process, obviously there is a risk of making mistakes and get hurt. Only after several attempts and long experience we will obtain an adequately safe skill. This is confirmed by accident statistics for debut cyclists and drivers.

We perceive the immediate surroundings as a whole

Road user behaviour is based on his/her general holistic perception of the road and the immediate traffic situation.

The information we require about our immediate surroundings is registered immediately by the brain through our senses. The brain automatically registers the contents of the visual information received through our eyes. In this way, without having to interpret the visual impressions, we form an immediate perception of the world around us. At the same time, our perception of the immediate situation is dynamic. This means that we register the direction we are moving in and what will happen "shortly" in the current space – just before it *actually happens*. For instance, drivers often go in a direction straight towards the crossing pedestrian ahead because we "see" that the pedestrian will have already reached the sidewalk when we reach and pass the crossing.

Our senses and brain are developed in interaction with the environment in a way that makes us receptive to the information we need. The more detailed the information we receive through our senses, the sooner we get a proper perception of the surroundings. In daylight it is much easier to get sufficiently detailed visual information compared to what we can achieve in the dark. This means that when driving in the dark, we may not always achieve an accurate perception of the road space. Worst case this can lead to misunderstanding of the traffic situation.

Driving a car involves three main tasks

Driving a car is a learned skill. For experienced drivers car driving is primarily an *automated action* which they perform without having to think more deeply about how they do it. A great deal of the time we can therefore think of other things while driving.

Through his immediate holistic perception of the road environment and without even thinking about it – the driver choses speed and position in such way that a *comfortable* safety margin can be maintained. The driver achieves this by driving in such way that his *perceived* safety margin in front of the car is longer than his *perceived* shortest stopping distance. The driver controls this by continuously adapting his driving speed.

The perceived safety margin of the driver is subjective. At the same time a true (objective) but unknown safety margin exists. The driver loses control when he/she overestimates the objective

(true) safety margin. To ensure compliance between perceived and true safety margin, the driver must be sufficiently experienced.

The driver solves tasks on three different mental levels: Control, Guidance, and Navigation.

The control task is the most important one as this must be performed continuously during driving. It is performed *automatically without conscious decisions* whereby the driver automatically adjusts speed and position to maintain a comfortable perceived safety margin (see description above). As long as the driver needs to perform control tasks only, he has reserves of mental capacity to think of other things, talk to passengers or listen to the radio. The mental reserve capacity also means he has "a wide range of awareness" or a large functional field of vision enabling him to register what is happening on and along the road in a relatively long and broad sector in front of the car.

The guidance task requires more capacity of the driver. When performing various manoeuvres such as lane changing or overtaking, the driver must make *perceptual assessments* in order to *consciously decide* whether a respective manoeuvre can be performed in the current traffic situation. Overcoming this task requires a high degree of focus and the driver's entire mental capacity. The functional field of vision is reduced and consequently the driver is at risk of overlooking traffic incidents which he/she would typically register during automated driving.

The navigation task is the most complex and the only task out of the three which may be characterised as problem solving. As such, the task *requires both understanding of symbols and logical thinking*. Reading and understanding of road signs, guidance signs and road markings as well as planning a journey from A to B are navigation tasks. If the driver does not already know the way he will have to use the various kinds of road guidance signs whilst simultaneously orienting in the road system to determine "Where am I?" and "Which direction should I choose?" The choice of direction will be based on previous experiences and use of the symbolic information conveyed on road guidance signs, road maps and GPS. The navigation task requires the driver's full attention and takes up his entire mental capacity.

Road signs will only be read when the driver has an immediate need for information
The driver needs to - at least briefly - operate in navigation mode in order to perceive and utilise the information on a road sign or road guidance sign. If the driver continues in automated mode (control task) or performs a demanding manoeuvre (in guidance mode) he is likely to miss the road sign and hence the information.

At automated driving the driver strives to maintain full control of the vehicle and he unconsciously registers from a long distance what is happening on the road ahead of the car. As soon as the driver observes a deviation from a distance, his curiosity and need for information are aroused. The driver will then "slide" into *guidance mode* enabling assessment of the situation. If he does not fully understand the situation, he begins functioning at *navigation level* by reading road signs etc. to collect information.

When a driver is using a road for the first time he is curious about the appearance of the road. He will be attentive and careful. He will need time to identify possible dangerous passages and will therefore need timely information from road signs, i.e. a warning about a dangerous curve on the road. The warning sign must contribute to creating the proper expectations in the driver thus avoiding surprises.

However, when driving on a road he knows very well, the driver will know how to drive and which speed to pursue along each section of the road. In such case the driver will not be reading the road signs since he has no need for them, except for orientation in the dark.

Good guidance
Good guidance requires readable early warning signs before every major intersection indicating the driving direction to a limited number of well-known geographical destinations.

Well-oriented in the environment
The road network must be constructed so that road users will always know where they are located (landmarks), and so that orientation in this is easy (simplicity).

The road user's expectations to the road and its continuation
The experiences we as humans accumulate throughout life in terms of the surrounding world and how we adapt to the requirements we encounter are gathered in a bank of knowledge that we carry with us. We take advantage of this also when driving.

Based on previous experience from similar roads and traffic environments we build up certain expectations about how to drive on the current road and which requirements it will pose on us. Even before entering a road for the first time, we have certain expectations as to how this looks. If the road is a national highway we expect the road standard to be relatively high. If the road is a minor road in a rural area, we expect it to be narrow and winding (Figure 3).

We have a natural curiosity about how the road looks the very first time we enter it. But already after a few kilometres we have built up an expectation of how the continued road will look. The natural expectation is that the road will continue as it began. However, if the road worsens, we prepare ourselves to meet an even worse standard along the way.

If the driver's perception and expectations to the road design and functionality do *not* correspond with the physical design and function, the driver will be surprised and confused. In a situation where prompt action is required, problems often occur because there is not enough time to take proper actions. Very often this will lead to human errors, which in turn can cause critical situations such as lack of reaction, excessively long reaction times, sudden and unexpected manoeuvres, etc.

When a driver has taken the same road several times thereby obtaining a thorough knowledge about it, he has even stronger expectations for the appearance of the road when driving it the next time. If the road has been reconstructed since the driver's last visit, the design of the road may not correspond to the expectations. The driver will then immediately start to reorient himself in the road environment and base his knowledge on the immediate visual impression. The challenge for the driver is then, that he will need sufficient time to act in a new unexpected way, if required by the reconstructed road.

Changes in the road environment pose increased demands on the driver. The road leading up to the change should therefore be constructed such that the driver will gradually lose recognition and thereby consciously begin to reorient in the new road environment.

When the road and the traffic conditions are in line with our expectations, no unexpected surprises occur. We then naturally have a high level of preparedness for the incidents and situations that we are expecting ahead. Correct expectations with respect to road design are therefore an important prerequisite for a well-adapted and safe driving.

The Self-Explaining Road

The general principles for road user behaviour defined in the Explanatory Model form the basis of *the Self-Explaining Road:*

- *The Self-Explaining Road refers to a road which is designed in such way that road users immediately perceive how to drive on this*
- *Road user behaviour is mainly determined by the driver's expectations to and perception of the road and the current traffic situation. Consequently, the road must be designed to meet driver expectations.*
- *This means that the road must have a clear and recognisable standardised design.*
- *The Self-Explaining Road must make it easy for the road user to go right and difficult to go wrong.*
- *The idiom of the Self-Explaning Road should make symbolic information dispensable.* Symbolic information (road signs and markings) shall primarily confirm the natural information expressed by the road design and must never be in conflict with this natural information.

Today "the self-explaning road" is a long-term design goal for all road designs. Creating the self-explaning road requires a continued development towards standardised, consistent and easily recognisable "design characteristics" for different types of roads and road sections of various functions.

In this process it is very important that use of symbolic information *always* supplement and confirm the natural information of the road design *without being in conflict* .

Recognition in the immediate holistic perception of the road and the traffic environment is a fundamental prerequisite to enable precise and accurate driver expectations of the road, both in terms of road design and traffic situations to prepare for.

The Explanatory Model is a tool for use in the development process towards realizing the Self-Explaning Road.

References

Nordic Human Factors Guideline. Explanatory model for road user behavior. Trafitec (2014).

Nordic Human factors Guideline project includes four sub-projects:

I) *Collection of existing knowledge based on comprehensive literature studies is presented in five thematic notes on road users´ physical and mental abilities*:

- Reaction time – break response time and decision response time
- Vertical eye level, reading distance, and reading time for drivers
- Walking speeds
- Assessment of speed and distance
- Inattention and distraction

II) *Development of an explanatory model for road user behavior* with the purpose of increasing the understanding of how drivers act in traffic and how our actions are influenced by road design and traffic environment.
Conclusions from the model form the basis of "The self-explaining road"

III) *Execution of a number of case analyses* for verification of the applicability of the explanatory model as a tool for problem analysis and solution of specific traffic problems in practice.

IV) *Three power point series with accompanying notes* for the dissemination of the main findings of the project:

- The physical abilities of road users
- The mental abilities of road users
- Explanatory Model for road user behavior.

All reports are available as downloads from www.nmfv.dk/vejgeometrigruppen

Figure 1: The Nordic Human Factors Guideline Project includes four sub-projects and creates the basis for the self-explaining road.

Figure 2: If the road is a national highway we expect the road standard to be relatively high.

Figure 3: If the road is a minor road in a rural area, we expect it to be narrow and winding