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DEUTSCHE GESELLSCHAFT FÜR VERKEHRSPSYCHOLOGIE E.V. (DGVP)

Ergonomic Approaches in Traffic and Transport Psychology

Basic Principals of Traffic Psychology for Human-oriented Infrastructure and Vehicle Design

INFORMATION-STATEMENTS-RECOMMENDATIONS

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Introduction

Traffic psychology focuses on the behaviour of road users and the application of its research to the understanding of practical problems. In the last century, traffic psychology has contributed not only to an extensive body of knowledge on the design of traffic spaces and vehicles but also on assessing fitness to drive, behaviour modification, training and education. By working with experts from other disciplines, ranging from construction and traffic engineers to vehicle and electrical engineers, as well as traffic lawyers, significant contributions to road safety have been achieved. Some examples of such successes are:

- Speed behaviour (e.g., in urban areas),
- Safety behaviour (e.g., use of seat belts and helmets),
- Observance of safety-related traffic regulations (e.g., driving without alcohol or drugs),
- Mitigating traffic conflicts between road users (e.g., at intersections and crossing points).

These successes suggest that an interdisciplinary approach, including evidence from traffic psychology, is an effective approach for improving road safety. However, the contribution of psychology is often overlooked by the public. Unfortunately, it is still common practice to start with only one element of the transport system to improve driver behaviour, without considering influences of the other system components (vehicle and infrastructure). To reach European targets, a more collaborative approach should be taken. Nonetheless, all stakeholders in the transport system are responsible for the safety of traffic. Both achievements and misses can be contributed to the traffic system as a whole, not to the single elements. If an accident happens it is not the fault of just the driver, but is a result of a bad interaction of driver, vehicle and situational factors.

Psychology and Design of the Traffic Area

When considering traffic safety interventions, the human factors approach should be considered as important. Specifically, behaviour in traffic within the framework of the "driver-vehicle-traffic environment" system cannot be understood without considering the effects of the physical environmental conditions. This is particularly relevant in regards to the effect of the road design on the road user. In this context, the conditions to which traffic participation, as a motorist or non-motorized person, must be taken into account in equal measure.

Motorized traffic

When considering motorized traffic, one question is how the design and layout of roads can influence traffic behaviour. Increasingly, these questions also arise regarding the safety audit of roads and any subsequent safety-promoting redesign. Important variables influencing traffic and driving behaviour are: conditions of perception, expectation, (risk) attitude, stress and strain, and the limitations of cognitive capacity. The impact of road design is often not considered as a factor that can influence certain behaviours. For instance, it can stimulate motivational states and therefore contribute to risky behaviours. Extensive research by psychologists on these influencing factors has demonstrated evidence of their effectiveness on safer road design. For instance, the *Positive Guidance* concept from the USA, the concept of *Self-explaining roads* in the Netherlands, and design work conducted by psychologists in German-speaking countries. It must be noted that there are considerable deficiencies in implementation. Specifically, there is often a large discrepancy between existing traffic related psychological findings and their implementation in the field. One of the reasons for this is that evidence-based findings are often not available in a quantified format, e.g., formal guidelines etc. The results may also be incompatible with design solutions, or have so few manageable psychological instruments available to record the consequential effects. Furthermore, traffic psychology is seldom involved in practical implementation or there may be too few psychologists willing to participate in practical implementation.

The design and construction of roads and traffic environment follow guidelines, which should be derived from the knowledge of:

- The underlying driving tasks and their subtasks;
- The resulting mental and psychomotor performances with which the respective driving tasks can be mastered (behavioural requirements);
- The associated possibilities and limits of human information processing as well as;
- The motivational requirements of road users and how these can be considered by design and construction.

The accomplishment of these driving tasks is based on a complex procedure of information acquisition and subsequent processing. The traffic environment (e.g., structural situation of the road, traffic flow, buildings, vegetation, use, signalization, routing, signage, etc.) conveys information to the driver (or to the road user in general), which they must then interpret and evaluate, based on experience with the same or similar situations. They then convert this into their own expectations about traffic flows,

the occurrence of certain groups of road users and their behaviour, as well as the feasibility of the appropriate driving operations. Therefore, behavioural and experiential design must consider that the road user is not only oriented to the state of development of the road space, but also to a subjectively shaped image of the overall traffic situation and the opportunities that present themselves to satisfy different driving motives and needs. This include the intentions of other road users with whom one must interact. This leads to what is probably the most important general design principle, known as "congruence of expectations". Specifically, that the situations anticipated by the road user, through the design of the road, should be consistent to the objectively signalled conditions. In situations where these expectations are incongruent, i.e., when the subjective assessment and objective conditions differ, the probability of errors, traffic conflicts, and collisions increases. For example, long straight roads and wide cross-sectional solutions (i.e., wide lanes), may encourage higher driving speeds. In addition, unexpected changes in direction, resulting a combination of curves with different radii are also associated with excessive variability in driving speeds and pronounced speed differences between curve areas. Such situation-dependent expectations are also influenced by the attention of the road user and the resulting stress level. Automatic and fast reaction patterns, which are developed through experience, must then be replaced by decisions during a novel task. Such design solutions may lead to uncertainties in behaviour and increase the risk of collisions.

When considering road design, it is therefore necessary to create a correspondence in the road and traffic image for the intended behaviours, i.e., to maximize the correspondence between situation anticipation, aspiration, and objective conditions. The notion of a "self-explanatory road" would result in the elimination of road signage. However, during situations where this is not possible, it would still be necessary to provide road users with the appropriate information about the upcoming situation. There are two main guiding principles for this, known as the inhibition and the guidance principle. The inhibition principle is based on inhibiting behaviour that is not appropriate to the situation. More specifically, it highlights the upcoming situation (e.g., "sharp curve") using a traffic sign, irrespective of subjective expectations, and calls for certain behaviour to be refrained from. Conversely the guiding principle links to driver expectations, thus attempting to achieve situation-adapted behaviour. For instance, using the principle of visual guidance, general information provided by prohibition and danger signs are supplemented or replaced by more situation-specific road markings and guidance devices, e.g. about a curve. If the most important elements of road design are standardized, then expectations can be learned in a consistent manner. Taking into consideration that most of the behaviourally relevant external stimuli are visual in nature, the human visual perception system and processing of such stimuli, as well as their behavioural relevance, should be considered important.

It is also important to identify an ideal balance between overload and underload in a route, and to avoid cues that can lead to the incorrect assessments of the route. This can be achieved by the sensible use of elements for the design of the route, e.g., traffic signs, street lighting, road markings, signal systems, etc. There is a wealth of psychological design rules for this purpose.

Non-motorized Traffic

The mobility of around half of the population includes pedestrians, cyclists, and users of public transport. Streetscape design and transportation infrastructure also need a clear perspective for these modes of transportation participation. Pedestrians and cyclists are overrepresented in the collision statistics, particularly amongst the very young and older age groups. Given that most of these collisions occur with motor vehicles, with the consequential severity dependent primarily on travel speeds and infrastructure, road design must:

- contribute to safe communication between motorists and other road users,
- ensure the ease of non-motorized traffic and its protection from collisions and injuries,
- reduce recognizable disadvantages of non-motorized traffic (which, among other things, increases the acceptance of safety-related regulations also on the part of pedestrians and cyclists),
- consistently apply self-explanatory, speed-reducing, and other safety-promoting measures in zones of mixed traffic and at crossing points,
- and, under certain circumstances, also ensure suitable spatial separation of motorized and non-motorized traffic without increasing the route lengths for pedestrians and cyclists.

In terms of sustainability, more attention should be paid to the concerns and requirements of non-motorized transport than has been to date. The ostensible disadvantages of such transport modes often prevent motorised vehicle users from switching to non-motorized transport for short-distance travel. Approximately 60% of all car trips are shorter than 10km, converting these trips to alternative non-motorised modes of transport, in combination with public transport use, could contribute significantly to improving sustainability concerns.

Theoretical models of traffic behaviour, developed from driver behaviour research, can also be applied to pedestrian and cyclist behaviour. More specifically, aspects taken from several models, e.g., the positive guidance concept, self-explaining roads, and even guiding or inhibiting principles, can be used as a basis for design and applied to non-motorised road users. However, to achieve this, they would need to be adapted to fit with non-motorised users' differential perceptions, communication, motivations, and actions. For instance, potential variations in the motives and abilities of non-motorised road users should be considered. One example of this is that children, adolescents, and elderly people may behave differently from one another in the presence of traffic, and these types of variations should be accounted for in road design.

Recent research in traffic psychology (e.g., survey and behavioural studies, conflict observations, accident analyses), has facilitated a basis for the design and evaluation of measures to increase road safety. One example of this is the concept of Shared Space. The design features of this concept include the principle of mixing all road uses and a removal of signage on the principle that all road users follow implicit rules.

Psychology and Vehicle Design

With the development of new information, control, and regulation technologies, various "visions" have emerged. These range from simple design elements, e.g., conveying the current driving and traffic environment, as well as relevant and situational traffic information, to scenarios of highly automated or even "autonomous" driving. For technical reasons, such infrastructure-related and/or vehicle-autonomous systems still are limited in terms of their effectiveness. The more "intelligent" these systems become, the more important it will become to provide information that is adapted to the situation and time. They will also need safe and transparent operating concepts, and vehicles must be designed so that they are oriented toward different user groups and their needs and interests. They must also account for the needs of the non-motorized road users with whom interaction must take place. It must also be clarified how new technologies will influence ergonomic requirements for road design.

Further questions for traffic psychology arise primarily from the application and use of new information, communication, and guidance technologies to influence traffic flow and behaviour. Current loads or disturbances in the road network are automatically detected and controlled according to variable message signs or variable traffic signs to inform the road users and to maintain the traffic flow. In addition to questions of recognizability, comprehensibility and processing of such information, cognitive-psychological considerations play a central role in the design and evaluation of telematic facilities (such as orientation structures and processes, navigation knowledge and procedures, etc.).

This brings us to the narrower "driver-vehicle" control loop, where we are dealing with an interface between a physical system and human system. This, in itself, demands special attention from psychology. Specifically, the "gap" between the two systems must be bridged, especially in terms of the exchange of information. In general, it is about the psychologically favourable design of coded information, e.g.:

- presenting information in an unambiguous and clearly understandable way,
- hierarchizing information according to driving task levels
- provide safety-promoting information redundantly,
- carefully selecting the type of information required according to modality (visual/acoustic/haptic) and quantity,
- evaluating information in terms of its motivational consequences and behavioural relevance and design it accordingly.

Therefore, an optimal information exchange between driver and vehicle is mainly based on the following criteria: the information presented must be timely, relevant, situation-specific, adequate, and clearly understandable. Importantly, it must also be accepted by the driver and motivate them to behave in a desired manner.

The increasing levels of automation in vehicles is leading to a change in the allocation of tasks between the driver and the vehicle/system. This results in a change to the stresses that the driver is exposed to. In general, the new tasks can be easier or more difficult than the comparable conventional solutions. Neither is right or wrong in principle, however, what is important is that there is neither underload nor overload on the driver. However, many isolated findings on specific designs of certain types of systems or their prototypes are matched by only a few fundamental considerations on the benefits and possible risks of such systems. The particular systems have so far been little related to each other, their technical realization is often suboptimal, and they are rarely adapted to the driver's information needs, processing capacity and motivational ability. Not everything that seems technically feasible is also sensible and useful for the individual road user. For example, it seems counterintuitive to progress high automation, which has system limits and exceptions, where humans are then needed as "trouble-shooters". Major problem areas that must be considered, especially considering the user are therefore:

- Actual information needs of the driver
- Possible distraction effects
- Quality of the (ergonomic) information presentation
- Management of the diverse information
- Transparency of system functions
- Acceptance by the driver
- Reactive behavioral adjustments
- Motivation of the driver
- Interaction of personal and situational components on the ability to take over the job
- Consideration of differently developed performance prerequisites, especially in the characteristics of information processing speed and cognitive flexibility/working memory.

In international standardization bodies (CEN, ISO), traffic psychologists are involved in the standardization of regulations, guidelines, and industry standards, which are intended to meet the requirements on the part of the driver and the traffic process. Their tasks include providing theories and models on the processes and requirements of driving, as well as on questions of cognitive, psychomotor capacity and coordination ability. They are also contributing research methods on information and communication processes during driving, establishing criteria (empirically), justifying limit values, developing measurement and evaluation procedures, and validating them in real traffic. However, the focus is not only on ergonomic aspects, but also on the question of how new information, communication and assistance systems can affect driving behaviour and communication with other road users (think e.g. on eHMI's). This centres around issues related to individual adaptation of the systems, as a function of driving experience, driving purpose, driving style, motivation, and other personal preconditions of the drivers. As well as how to avoid compensation and adaptation processes related to a changed risk assessment, along the problem of delegation of responsibility from the driver to the

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Further references available on request

system – and along with all related to the "ironies of automation". Possible negative effects of system-related behaviours, i.e., the interactions of road users with each other, on traffic flow, and on road safety, are issues that may influence market penetration of automated vehicle systems, particularly when we consider the variable levels of automation in traffic. In this context, traffic psychology, in close cooperation with the engineering sciences, must solve a multitude of tasks that effectively complement and exceed its diagnostic and behaviour-modification efforts in the context of assessing fitness to drive. After all, traffic represents human behaviour and communication in public space, and their analysis, understanding, and control are the subject and task of psychology.

Conclusion

The human factors approach to traffic space and vehicle design has considerable potential for improving traffic safety. Traffic psychology should therefore always be included in practical implementation.

- Road design should be required to create a phenomenal correspondence in the road and traffic image for the intended behaviours. This will maximize the correspondence between subjective situational anticipation, aspiration, and objective conditions. Too seldom is attention paid to the stimulating nature of road design. It can stimulate certain motivational states and, in this way, contribute towards risky behaviour.
- Since we are dealing with an interface between a physical system and the human system, the attention of psychology is required. A smooth and, if possible, error-free exchange of information between these two systems must be ensured. It is thus a matter of the psychologically favourable design of information.
- In close cooperation with the engineering sciences, traffic psychology can contribute to the solution of a wide range of tasks. The analysis and influencing of human behaviour and human communication in the traffic environment are the subject and task of traffic psychology.

Literature on request from the authors.
This expert statement is a translation of the German version 08/2020. It represents the binding position of the DGVP e.V.