SENSES & SENSIBILITY
IN LISBON
DESIGN, MARKETING AND VISUAL CULTURE IN THE RIGHT PLACE

2011
6TH INTERNATIONAL CONFERENCE
6TH UNIDCOM/IADE INTERNATIONAL CONFERENCE
6TH TO 8TH OCTOBER
DRAWING RESEARCH NETWORK CONFERENCE
5 OCTOBER

PROCEEDINGS BOOK
AFFORDANCES IN THE DESIGN OF ROAD ENVIRONMENTS: FOR BETTER ROAD SAFETY
PAULO NORIEGA¹
ELISÂNGELA VILAR¹
EMÍLIA DUARTE²
FRANCISCO REBELO¹
¹ ERGONOMICS LABORATORY, FMH/TECHNICAL UNIVERSITY OF LISBON, CRUZ QUEBRADA, PORTUGAL
² UNIDCOM/IADE, LISBON, PORTUGAL

Keywords: affordances, learning, road safety, ergonomics, design

Abstract
According to the World Health Organization (WHO) (2004), road fatalities are one of the leading causes of death in the world, accounting to nearly 1.2 million fatalities and about 50 million injured people by year. Although road accidents have a multifactorial etiology, too often the responsibility is assigned solely to the drivers' lack of civility. This paper advocates an environmental perspective of road safety, based on the ecological approach to visual perception (Gibson, 1986). Therefore, it raises the hypothesis that the essential problem is not the drivers' disobedience of the rules, but a road design problem. It is argued that driving behavior can be changed by structurally manipulating the road. By giving examples of studies on driving behavior and visual perception, it is demonstrated that the design of environmental affordances can lead the drivers' behavior, therefore reducing danger. In practical terms, drivers learn to drive on the road as well as by imitating other drivers. In this sense, the environment plays a key role in the drivers' learning process. That is, if roads are poorly structured, they will provide an incorrect learning environment, and as a consequence, the occurrence of errors shall increase. If these errors become a common fact, the likelihood of being multiplied, by a social learning effect, is greater. Thus, roads are hazardous environments where errors and accidents are frequent.

1. Introduction
In the book "Human Factors for Highway Engineers" the authors (Fuller & Santos, 2002, p.1.) described the following scenario:

"Imagine someone enthusiastically bursting into your office with the news that they had invented a new system of transportation on land, a system that was cheap for users but which also offered a range of extra
benefits depending on how much you were prepared to pay, a system that could be used by young and old alike to enhance their mobility and enable them to cover large distances in a reasonable time, a system that was usable at all times and in all but the most severe weather conditions. And it would be so popular that the average person in the developed world would use the system to cover thousands of kilometers annually.”

The story continues with the costs of this system. By year, approximately 1.2 million people would die worldwide; plus 50 million would be injured (WHO, 2004), and the material damages would be huge, etc. In light of these previsions, if we had the chance to choose between having or not having this system, obviously we would tell that person to return to his/her office and invent another system. But, the truth is that we are using such a system and, despite the great advantages of car mobility, the associated costs are dramatically expensive.

Nonetheless acknowledging that there are multiple causes associated to road accidents, in this paper a perspective based on the knowledge about the human factors in driving is presented, which emphasizes the intervention on the road’s infrastructure as a way to initiate a good driving behavior. The direct perception approach, adopted as a model of inspiration, argues that human beings use the affordances of the environment to guide their behavior, requiring no construction or cognitive mediation to act (Gibson, 1986). We advocate an ideal concept of the road that automatically elicits a correct driving behavior.

Emphasis is placed on this perspective because straightforward explanations for road accidents are abundant and can be summarized in the following statement: “Drivers are the responsible for the high rates of accidents. Drivers suffer from a chronic lack of civility. Basically it’s a cultural problem”.

Solutions that come associated to such a standpoint are often: the tightening of norms and enforcement measures, media campaigns to change attitudes, and educational measures. Throughout this text we explain why we prefer to emphasize other solutions to the problem of road safety.
Since interventions at the level of road infrastructure are highlighted as being determinant in changing behaviors, we should then answer the following question:

How can the structure be responsible for road accidents?

The structure may be responsible for accidents in two ways: Directly – a poor road surface, a hole in the road, an incorrect or ambiguous road sign, etc., are all conditions that boost the probability of accidents; and Indirectly – through the process of learning to drive. Drivers learn in the environment in which they drive, and also by imitating other drivers. In this sense, the environment’s affordances play a key role in the learning process. That is, if the road environment is poorly structured, it will endorse an incorrect learning process, and then the occurrence of errors. If such learning errors are very common, the chance that they multiply further, by the effect of social learning, is enhanced. As such, we will have a road environment where many errors take place.

In short, there are a lot of incorrect driving behaviors, whose direct consequence results in the high accident rate. What no longer can be said is that the main direct cause of the accidents is the drivers’ lack of civility.

2. Suitable Learning In The Road Environment

A well-designed road structure may be the initiator of a good driving behavior. We support this assertion by explaining, on the one hand, the operant learning mechanisms present in driving and, on the other hand, the mechanisms of social learning (imitation of the behavior of others).

2.1. Operant Learning

In a behavioral analysis of learning (Fuller, 1993), one might say that behavior is governed by its consequences. Behavior that is followed by a positive consequence is strengthened and the one that is followed by a negative consequence is avoided.

Naturally, the relation between behavior and consequences is not independent of context. This means that such a relation (if I make “x” then “y” happens) is defined by antecedent or concurrent events. The relation – if I travel fast, then I arrive on time – is also dependent on antecedent factors such as the presence of police or other cars.

This type of analysis is referred to as ABC (Antecedent-Behavior-Consequence) (Fuller, 1993), because the relationship

---

1 According to an OECD report, quoted by Stewart et al. (1993), a driver needs an average of about 100 000 km to be considered experienced enough to drive safely in the perceptive complex task of driving.
between behavior and its consequences is typically conditioned by antecedent events. Thus, these antecedents, called stimulus of control or discriminative stimulus, control the behavior. According to this author, ABC, as a means of behavior analysis, provides a framework for incorporating learning processes and motivation into the human factors investigation and, more important, it highlights the role of stimuli and events that, by being present, can control behavior.

For Fuller (1993), the quality of learning to drive, safely or unsafely, results from the confrontation of high amounts of ABC type contingencies, which are present in the road. An increased problem for learning is that the predictability of these contingencies often works on a probabilistic base. During learning, the negative behavior can be more reinforced if the probability of being rewarded is higher than the probability of being punished. This can be observed, for example, on the rural roads where there is no police vigilance, in places where high velocities have been registered, or close to intersections, locations where drivers think that it is very unlikely other vehicles to appear.

In short, since the contingencies between a rewarding behavior and a punitive consequence are unlikely, drivers learn to take the risk. With such process, the experience that is necessary for learning to drive can lead to an incorrect adjustment.

For Fuller (1998), a systematic management of the learning process can counteract the effects of learning resulting from an unsafe behavior. That management involves the manipulation of background events controlled by the discriminative stimuli. The learning, or the change in behavior, is dependent from the discriminative events that specify the relation between a given behavior and its consequences. These stimuli consist of traffic signs, road humps, the road layout, etc. But, in order to be effective, they must comply with a set of rules (Fuller, 1998):

- Clear and unambiguous: avoiding providing incorrect or ambiguous information to the driver. This means, for example, to include data about which road to follow and about the junctions' or intersections' features. As well as to adequately draw drivers' attention to the presence of surveillance cameras or road humps. It means acting through the discriminative stimulus, instead of acting by the consequences. It is preferable to discourage bad behaviors than to punish them, since punishment implies that the bad behavior has occurred.
- Consistent: if a given sign is used to mark the presence of a bend of particular severity, then the same sign should always be used for such cases and that sign should be exclusive for that bend type.
- Reliable: the most obvious example is the signaling of roadwork ahead, which often remains in the same place indefinitely, even after the works have been finished a long time ago. Drivers learn to not
slow down, unless they see obvious indications of works, such as machinery or workers on the road. Another and even more problematic example is the children-crossing signs, intended to signal a lower speed limit for specific times within a designated area of roads around a school. Since these discriminative stimuli are always present, even when they are irrelevant, drivers learn to ignore them (habituation). Naturally, adding flashing lights during the times where children may be in the area can increase the reliability of those signs.

2.2. Social Learning

Another issue in focus, related with learning, refers to social learning. Besides learning in the environment, drivers also learn, or adopt, behaviors by observing other drivers. Such assumption is presented by Groeger (1995) that, in reviewing a study about driver’s traffic law compliance, concluded that the effects of the normative information are very reduced and are intrinsically dependent on the observation of the other drivers’ behaviors.

The papers reviewed are related to the observation of traffic law compliance (e.g., the speed limits). The studies were conducted in natural conditions and tested the compliance with the rules according to: (1) increase of the transgression probability to be detected; (2) increase of the transgression detection consequences (e.g., raise the punitive level of the traffic fines); and (3) the effect of providing information.

(1) The increase of the transgression probability to be detected was manipulated by placing a police vehicle to do monitoring, on the side of the road. The average of the imposed speed limits’ violation was assessed. In summary, these studies show a reduction in the vehicles’ speed, which is extended in hallo over an area around 1 km. Such a result only occurs in places where there is surveillance. There is also a great variability in the speed drop, which only decreases as vigilance extends in time, that is, if in the next day the surveillance is absent, the speed returns to previous values. However, after a period of five days of constant monitoring, once the surveillance is absent, it is noted a residual effect on the drop of the speed that lasts around six days. Attempts to demonstrate the promptness of actuation of the police taking measures regarding the violators, was manipulated by placing another “offender” vehicle being fined by the police. This manipulation had similar results to the ones attained with the presence of the police car alone. Another studied manner of manipulating the probability of detecting violations was through the correlation between the number of traffic fines and the average of the speed drop. Studies referred by

---

2 Normative information is considered those emanating from a legal code such as, the speed limits and those that are transmitted through signaling.
Groeger (1995) suggest a weak relationship between the number of traffic fines, imposed in a given road section, and the speed. There was no relationship between the duration of the police surveillance / number of traffic fines, the average of speed and the rate of accidents.

However, the adoption of an automatic system to traffic fining the violators without requiring human intervention resulted in a reduction, in a weeks time, from 800 violators registered to half and, in the subsequent weeks, to about 20 transgressions per day. It was concluded that by reducing the uncertainty about the probability of the violation to be detected, the fines are successful.

(2) The second type of works, regarding the observance of the rules, was related to increasing the severity of the penalties. Groeger (1995) refers that, although being intuitively appealing, the idea that legal threats - if the threats are perceived as being immediate, unavoidable and severe - are able to effectively control the behavior, has not been widely supported by empirical studies of criminal law. In general terms, the increasing of the consequences has little effect over time, being effective only in a period close to the entry into force of the new penalties which are more punitive. This is because, at that time, they are accompanied by more frequent law enforcement. After a certain period of time the effects on lowering the number of transgressions, associated to the worsening of the consequences, tend to reduce and return to the previous figures. Therefore, the severity of the penalty itself is not discouraging, especially in situations where the detection of the infringement is most unlikely.

(3) The third type of works is related with the effects of providing information to the drivers. These studies show that, public information campaigns alone have no effect on the observance of the rules, however, when articulated in conjunction with the reinforcement of the police, their effects are strengthened. Some studies have tested the transfer of information, about a campaign on speed detection, in the media. The days in which the information was broadcasted were compared to those in which no references were made. Lower speeds were registered on the days in which the campaign was mentioned in the media. Another case of information is related to traffic signs. For example, traffic signs such as “speed checked by radar” are effective only when, in fact, there is also the police force watching. This effect remains even in cases of more sophisticated signs that tell the drivers about their speed and, when the limits are exceeded, warn them about the need to slow down. It is concluded that this type of information (campaigns and traffic signs) are effective only with the mediation of the police force presence.
In what refers to providing information through campaigns, it should be referred that Cunha and Gomes (1993) question the effectiveness of road safety campaigns based on the study of the primus inter pares effect, on a sample of Portuguese drivers. In that study the authors concluded that the majority of the Portuguese drivers (65.6%) believe they have driving skills above the average and that the campaigns aiming to increase the compliance with safety rules are not addressed to them but to other drivers. Such effect is not exclusive to the Portuguese culture. Guerin (1994) describes a similar effect observed in a sample of New Zealand drivers. However, still regarding the effects of providing information to the drivers, Groeger (1995) refers to a series of systematic works about a signaling technique named “collective feedback” that seems to be more effective regarding compliance with rules. This technique consists of having a sign that indicates the number of drivers that, in a given time period (previous day or last week), exceeded a certain speed limit. This type of sign was able to reduce the speed throughout the 26 weeks in which it was under trial. It was more effective than the police vigilance and did not cause an over-reaction similar to that found when seeing the police, that is, to slow down more than necessary.

Besides these three types of studies, Groeger and Chapman (1994), developed a work in which they also studied the adherence of driving recommendations. One recommendation studied refers to inter-vehicles safety distance, which was defined in their study as one-second minimum distance. A number of experimental conditions were manipulated: the placement of signs indicating the minimum distance; an auditory alarm to warn the drivers when the distance decreased to less than one second; and the fact whether the other drivers were complying or not with the recommendation about the distance. The results revealed that the auditory alarm was effective in maintaining the inter-vehicles' safety distance and that the traffic signs were not effective. As for the other drivers' adherence to the recommendation, if they were found complying or not with the recommendation about the distance. The results revealed that the auditory alarm was effective in maintaining the inter-vehicles' safety distance and that the traffic signs were not effective. As for the other drivers' adherence to the recommendation, if they were found complying with the inter-vehicles' safety distance then the participants' compliance was elevated and the inverse was also true. However, when mixing the experimental conditions it must be noted that the auditory alarm was found effective in all conditions.

This review of Groeger (1995) questions compliance with rules, in the road environment, simply because they exist, they are the law. Namely, the use of signs, the adoption of more severe penalties and even the exclusive use of information campaigns as a means to change the driving behavior. What seems to be effective on increasing the compliance with the rules is, firstly, the direct perception that there is an increasing likelihood of being traffic fined (e.g., the proximity of a police car) or, secondly, when there is, at the
group level, compliance with the recommendation (e.g., the collective feedback sign or the observation of the inter-vehicles’ safety distance being kept by others). For the observance of the rule, what matters is what the driver perceives as being transmitted by the surrounding environment and not what the driver asks about himself. That is, drivers guide their behavior based on information readily available about themselves and about the environment affordances and not based on exhaustive questions about themselves or about the actual driving task. In this sense, learning is also dependent on the observation of the others’ behavior, as seen in the works about the feedback signs and inter-vehicles distance.

One aspect that must be noted about the Groeger and Chapman’s study (Groeger, 1995; Groeger & Chapman, 1994), is that the auditory sign used was always effective, regardless the conditions in which it was used. This is interesting because the discriminative stimuli for the rule violation (inter-vehicles distance) was given by the vehicle itself, and through a sensorial channel other than visual, which was the one more filled by the driving task.

This result reinforces the “problem” of the automatic nature of driving and the relative importance of rules. First, because as we have seen, there are several factors interacting in rules obedience, and then, because there is a sparse relation between the violations of the rules and the accidents frequency. Carsten (1998), when referring to the (already) commonplace that the human factor is responsible for 95% of the road accidents, alerts to the danger of this cliché that only blames the operator of the vehicle rather than those involved in the design of the system or the operators of the road system as a hole. Carsten (1998) reported detailed studies about accidents that prove that intentional transgressions are the factor with the smallest contribution to the accidents’ rates, being the basic errors3 the most frequent and those that contribute to most accidents.

3 How To Influence The Drivers’ Behavior
Beyond surveillance and punition as manners of influencing the drivers’ behavior there are other alternative ways to interfere. A more ergonomically based and scientific analysis of the accidents can change our vision about the causes underlying the accidents, as well as about the measures that can be taken to avoid them. A base principle of ergonomics is that the human operator should be blamed only for the accident. That is, one should seek for the causes of the accidents in the system in which the human is operating, causes which, from an ergonomic point of view, originated due to an incorrect design of the Human-machine interface and/or Human/“environment” resulting, therefore, in a poor adjustment of

3 Faults and slips
such causes (machinery and “environment”) to the human operator.

According to Brown (1997), the ergonomics approach, based on the information processing paradigms, allows one to objectively measure the tasks’ requirements, leading to the concepts of system workload and user’s information processing capability. Based on the ergonomic approaches, we had started to consider a more proper allocation of tasks between the human operator of a system and its technological components. The most significant consequence, in terms of road intervention, according to Brown, is that errors and accidents are not necessarily better addressed with corrective measures, i.e., education, training and law enforcement. For the author, such measures can indirectly modify the behavior through changing attitudes, knowledge, understanding and/or skills. Conversely, the psychological explanations, which are based on human error in complex systems, emphasize the need of using engineering methods that provide support to a fallible human behavior. Thus, these measures operate a direct change in the behavior, by modifying the task’s demands.

Several studies provide support to this form of intervention in the area of road traffic. When referring to the analysis of the driving task, we realized that most of the time spent conducting the task performance is performed at an automatic or almost automatic level. Therefore, driving is an activity largely “automatic”.

While driving, you can talk to the passenger aside, listen to the radio, and drive at the same time. This is feasible because of the automatic component of driving, where perceptive motor mechanisms are activated from previous learning and training. If after the completion of a course you ask the driver to evoke or describe places where he went, he/she did not always have such ability because, since driving is automatic, the elements of the course may not be relevant enough to be retained in memory. A classic example relates to the maximum level of performance in the registration of traffic signals. In a field study conducted in Sweden (Rumar, 1994), drivers were stopped after passing a traffic sign and were asked which was the last sign that had just passed by. The results showed that 50% times, in average, the drivers did not remember the signs; this average varies depending on the type of sign.

Examples like this raise some doubts on the effectiveness of regulatory measures because driving is not a purely conscious activity. Moreover, there are studies that suggest the possibility of intervening on the driver’s behavior through design and engineering measures that require the driver to drive properly, or even that promote the adoption of a correct behavior without the driver realizing that he/she is being “conducted”. The road humps are the clearest example of such type of engineering measures that
force the drivers to slow down. Another example is given by a study conducted in two roads where the speed and the number of accidents was found to be above the average, and where the reduction of speed was achieved by adopting simple engineering measures (Waard, Jessurun, Steyvers, Raggatt, & Brookhuis, 1995). The road infrastructure changes were designed to produce discomfort for the speeding driver by providing noxious auditory and haptic feedback. On experimental roads, smooth-surface road width was reduced by using blocks of gravel chippings placed along the centre line and at the intervals on road edges. As a result of these measures, the vehicles’ average speed decreased. When drivers were misaligned from the lane’s axis, they received kinesthetic and auditory cues from the rough surfaces that, by causing discomfort and increasing the perception of speed, forced them to reduce the speed. The results of this study were made possible through a previous understanding of the nature of the alignment task and the visual cues (side guides), as well as of the mental workload models that assumed that a mental workload increase (task complexity) would result in a speed reduction. In other words, as the visual cues were eliminated and the width of each lane decreased, the alignment task’s difficulty and the mental workload increased. Since the alignment has become more difficult, the driver would slow down or was “punished” with the discomfort caused by the bumps of the rumble strips.

In another study (Horberry, Gale, & Bolarin, 1999; Horberry, Halliday & Gale 2002.), a solution to prevent high vehicles from beating on low bridges in attempting to pass beneath them was assessed. This is a frequent problem in the UK and it is due to an inaccurate perceptive judgment of the bridge’s height by the drivers, together with the fact that they are not aware of their own vehicle height and do not see or regard the signs about the bridges’ height. The authors hypothesized that if the bridges seemed to be lower, the drivers would be more precautious. In fact, through an optical illusion effect, made on the bridge’s façade, the perceptive evaluation of its’ height was that it was lower. With this design modification, the drivers of high vehicles were more cautious about passing beneath low bridges.

Other interesting studies on cognitive categorization of roads (Kaptein & Theeuwes, 1998; Riemersma, 1988; Theeuwes, 1998) enlighten the importance of the environment design in driving. What these studies suggest is that drivers categorize cognitively the different types of roads. The experience with each type of road contributes to that cognitive categorization and it is often different from the roads’ normative categorization (legal). According to each category cognitively established, the driver has an expectation about the environment type and its behavior is adapted to that and, in part, is driven by such expectations. Naturally, if their expecta-
tions or cognitive categorization are coherent with the normative categorization established for that specific road, then the likelihood of error is smaller, since the behavior will be properly adequate to the environment. In other words, if we are on a road that, by its’ design, is cognitively categorized as an expressway, the presence of a speed limit sign of 50 km/h will not be able to slow down the speed.  

4. Conclusion  
Since the road accidents have multiple causes, the prevention measures must necessarily be diverse. What the studies reviewed in this paper suggest is that, although necessary, the police measures and the media campaigns are somewhat limited. The police surveillance effectiveness would be maximized if it was permanent in time and space. When a rule transgression occurs, the driver should be absolutely certain that he/she would be immediately ticket fined. Obviously, a surveillance system of this nature is virtually impossible. The campaigns have little effect over time and, since driving is mostly an automatic activity, eventual changes in general attitudes intended to promote, for example, observance of speed limits, do not ensure a change of the driving task’s automatisms that are learned during the actual driving.  
A good preventive measure is the one that promotes the learning of correct behavior from the environment where they are learned, that is, on the road. Based on detailed knowledge about the operator / driver, we can look up to the road environment’s good affordances as a product of ergonomic intervention that, if adequately designed or optimized, promotes appropriate learning in the environment as well as adequate driving behaviors.  

References:  


