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Perception of 3D Virtual Road Markings - Based on Estimation of Vehicle Speed

Excessive speed and poor drivers' perception are the causes of a large number of traffic accidents. Analysis of the influence of geometry in drivers' behavior has been widely performed by different researchers. One way to improve road safety is to provide adequate visibility in order to help drivers adopt adequate behaviors. When the budget is not sufficient for expensive traffic solutions, innovative but simple solutions can be implemented. In this study, the experiment was performed to explore how drivers' perception and behavior are influenced by two virtual 3D shapes' projections – a 3D alternative crosswalk pattern and speed bumps consisted of triangular prisms. The results show statistically significant differences between drivers' willingness to reduce vehicle speed as a response to the two types of road markings: the first one with the square shape base (rectangular prism) and the second one with triangular shape base (triangular prism).

Keywords: *Perception, 3D Road markings, 3D pedestrian crossing.*

1. INTRODUCTION

Analysis of the influence of geometry in drivers' behaviour has been widely performed by different researchers. In-depth accident investigations have shown that excessive speed was a contributing factor in about one third of all fatal crashes. Road accidents can be determined, among other reasons, by a wrong layout design. Significant part of traffic accidents also results from drivers failing to grasp the road situation, i.e., aberration of the visual perspective and losses of visibility due to road geometry (obstacles, variations of the horizontal alignment or section, etc).

Driving is the result of a psychological process that translates data, signals and direct/indirect messages into behaviour, which is continuously adapted to the exchange of varying stimuli between man, environment and vehicle. These stimuli are at times not perceived or correctly understood by the driver, even if they derive from tools specifically conceived for his safety [1]. The result is unsafe behaviour. For this reason, the road environment needs to be radically redesigned. The main issue is how to integrate road design with drivers' performances.

For this reason, the road environment should be planned and designed in order to guide the user towards the most adequate and safe choices. One way to improve traffic safety is to provide adequate visibility in order to help drivers adopt adequate behaviours (speed, headway, etc.). Help can come from the infrastructure (traffic control systems). When budget and financial situation do not allow the implementation of expensive traffic solutions, some of them can be replaced by innovative, but simple solutions.

A number of different measures, including new traffic signs, road markings and painted speed bumps are being introduced to reduce traffic speeds. They use multi-coloured paint to create an optical illusion of a three-dimensional raised surface when viewed from the perspective of a driver. Modern software tools, based on basic geometric principles, opened new design possibilities for the creation of road markings, aided by adequate testing the reaction of a driver by virtual reality (VR) applications. In addition, for the time being, in the testing segment, modern 3D printing can also be of great significance.

The virtual hump is the latest innovative solution adopted as an alternative to the traditional "sleeping policemen", which have been criticized for damaging cars, slowing down emergency vehicles, and lowering fuel economy. The idea with faux speed bumps like these is to catch drivers' attention just briefly enough to get them slow down, but not so much that they cause a traffic disruption. The first such "lying policemen" were drawn in 2008 in Philadelphia, in the United States, and later 3D footpaths appeared in other parts of the world. Furthermore, a number of cities around the globe are testing 3D-painted crosswalks in order to slow traffic,

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starting from New Delhi, and is now being tested in South Africa, Britain, US, China, Russia, Ukraine, Kyrgyzstan, New Zealand, Iceland and most recently in Greece. The 2D designs use perspective to create an illusory bump to oncoming vehicles. The images will appear as 3D barriers to oncoming motorists, although the road is completely flat.

A "3D" zebra crossing has been painted which gives the optical illusion of the white stripes floating above the ground and obstructing the road, causing the drivers to slow down. But as they get closer to the crosswalk, its apparent image became flat, so they continue to drive through without braking (which has led to accidents although physical speed barriers have been used).

The analysis of various aspects of the impact of geometric characteristics on the functioning and safety of traffic, as an indication of the importance of geometric design in traffic, was reported in the study by Hasson et al. (2015) [2]. In the near future, the realization of testing and implementation activities of the new generation of intelligent traffic systems, based primarily on the use of autonomous vehicles, will be expressed. Certainly, for the smooth functioning and exploitation of these vehicles, the necessary precondition is to provide adequate traffic infrastructure and road signalization. Assuming that the input data, which system for decision-making in autonomous vehicles is processed and used to determine basic motion characteristics (direction, speed, stop, etc.), is collected by sensors and cameras, the great importance for making the right decision has a clear and precisely defined traffic environment. Hasson et al., (2015) [2] discussed how those technologies will affect geometric design decisions in the future. Accordingly, 3D road markings adapted to the aforementioned modern systems are a convenient way to provide the necessary information from the traffic environment.

1.1 Road geometry and traffic safety

The roads are designed with the aim of facilitating the stability of vehicles and guarantee the perspective view of the external environment. The designer studies the geometry (the sequence of straights and curves), defining the speed in order to ensure high standards of safety and ride comfort [3]. The user of the road, however, interprets the layout. In the most cases, he uses the available space to adopt behaviors that are inconsistent with the choices of the designer. Speed is the predominant factor in road design, i.e. it is the key parameter in the study of the effectiveness for each proposed design solution.

Geometric design refers to the selection of roadway elements such as the horizontal alignment, vertical alignment, cross section, and roadside of a highway or a street. A good geometric design has to provide appropriate levels of mobility and land use access while maintaining a high degree of safety. The balance between mobility/accessibility and safety is often reflected by the "allowed" vehicle speed on the roadway element [4]. Driver behavior is complex and involves many different factors often at odds with each other and therefore complicated to predict. However, speed and excessive speed remains a main contributing factor to road crashes and is an important factor in road safety [5-7]. Drivers select the speed at which they travel as a function of a variety of driving clues and risk assessment, directly affecting the operating speed of that road. In reverse, the road environment affects the drivers speed choice. Operating speeds are fundamental to the development of any roadway corridor and are used to determine appropriate roadway design elements [8].

Traffic safety policies can be implemented in different ways: enforcement, increasing user awareness, and engineering countermeasures. Currently, speed reduction is mainly achieved through law enforcement and the implementation of traffic calming measures. The engineering part of the matter involves interventions on existing roads in order to reduce the expected number of accidents.

There are many measures in place to reduce speed and protect all categories of traffic participants on the roads; these include Lollypop ladies, chicanes, zebra crossings and road humps made of tarmac. The Ramp People provide durable, temporary solutions. For the traffic calming ramps there are several terms in usage, such as speed ramps, road humps, speed bumps and sleeping policemens. Speed cushions which are designed to be easy to install whilst quietly and effectively slowing road traffic without vehicle or tyre damage are also in use.

However, apart from the method employed for choosing countermeasures, there is a lack of theoretical approaches able to take into account users' reactions to modifications in infrastructure. An alternative speed reducing approach is to encourage drivers to voluntarily choose an appropriate driving speed [9]. Road geometry and other characteristics will influence drivers' expectations of the appropriate speed for a road and when an inconsistency exists that violates driver's expectation. The driver may adopt an inappropriate speed or inappropriate maneuvers, potentially leading to road crashes [10]. When traffic calming treatments rely on physical obstacles, such as speed humps, they can be very unpopular with both residents and road users, and can create new problems associated with noise and maintenance. Some work has been carried out to directly investigate the effect of a roadway design on driver behavior through controlled manipulations and to quantify the safety benefits of geometric design [11]. It is clear that such point of view offers interesting potentialities in road design, where the "traditional" choice of the layout (on technical basis) is aimed to regulate drivers' behaviors but is not always sufficient to achieve this scope.

In cognitive psychological terms, approaches to improve road safety imply two complementary avenues. The first is to identify and use road designs that afford desirable driver behavior. Perceptual properties such as road markings, delineated lane width, and roadside objects can function as affordances that serve as builtin instructions and guide driver behavior, either implicitly or explicitly [12]. To be effective, it is important to select the combination of features that will afford the desired driver speeds and ensure their consistent use [13]. However, the potential benefits of 'psychological traffic calming' are being investigated to assess whether speed reductions can be achieved without using speed humps. Changes in the road environment have been studied to see how do they affect driver behavior [14]. It has been demonstrated that computers and machines can be designed to influence human behaviors, positively bending the will by means of a persuasive action [15]. Within the framework of the above mentioned, the research aims to understand how the interpretation of drivers' behavior in a virtual environment (immersive type) could facilitate the identification of road design tools suitable for controlling the reaction of drivers.

1.2 Virtual reality

In many domains, the benefits of VR stem from the ability to create recognizable, three-dimensional facsimiles of real objects in space. The advantages of VR are that it allows greater control over stimulus presentation; variety in response options; presentation of stimuli in three dimensions; the creation of complex scenarios; the generation of varying levels and combinations of multimodal sensory input potentially allowing audio, haptic, olfactory, and motion to be experienced simultaneously to the graphically rendered environment or objects; the possibility for participants to respond in a more ecologically valid manner; the precise and independent manipulation of the geometric and photometric relationships between objects; the possibility of examining sophisticated complex partici–pants behaviors, such as avoidance; and the study of situations which can be impractical, dangerous, or ethically questionable to be created in real life [16].

VR cannot provide a magic solve-all solution to these questions about cue utilization and integration but, in combination with traditional experimental techniques, it offers a bridge towards studying sensory perception in a controlled, principled fashion using stimuli that realistically reflect how we interact with the world [17].

Road accidents can be determined, among other reasons, by a wrong layout design. An aberration of the visual perspective and losses of visibility due to road geometry (obstacles, variations of the horizontal alignment or section, etc.) can be, together with weather and environmental aspects, the cause of inappropriate behaviors of drivers. The environment is characterized by different factors, road pavement and horizontal markings included [3]. It can be studied on site, but also by means of virtual environment.

Detailed and in-depth analysis of information con–cerning drivers' behaviors related to the road scenery driven through, became possible when the road layout is studied in a virtual environment. Several authors confirm that human behavior in a virtual environment can be considered sufficiently representative of reality, particularly when its reconstruction is accurate [18, 19].

Virtual environments (VEs) are applied in many areas such as entertainment, vehicle simulation, industrial and architectural design, training, and medicine [20]. A VE is an artificial world that can be presented visually on a desktop display, a head-mounted display, or on one or more projection displays, sometimes combined with (spatialized) audio, haptic feedback, and sometimes even scents or thermal cues. These mediated environments are thus able to provoke responses and behavior similar to those portrayed in real environments.

The study of a driver behavior in a virtual environment for road design purposes is a research field which is sometimes not accepted due to factors of visual technology and environmental reconstruction. However, it can be demonstrated that virtual reality (VR) could be a tool for a forecast of drivers' behavior in different situations.

It proves to be useful in the representation of real behavior, but also it can become a design instrument because it can forecast the effects of road modifications before they are carried out [1].

With the reproduction of real environments in the laboratory, all design choices can be simulated, corrected, modified, and refined in a fast-cyclic process that does not require expensive works and adjustments. So, it becomes a valid instrument for the evaluation of interventions aimed at improving road safety, such as modifications of road signs, geometry, or the driving environment in a more general sense.

Since many of the advantages of VR as an experimental tool are derived from the ability to place the participant inside the scene, it is not surprising that a lot of research has been conducted into the concept of presence—the extent to which the user feels as though they are "really there" [21, 22]. Presence is viewed as crucial to having participants respond the same way in VR as they would in reality but remains a difficult concept to measure objectively [22–24].

"Immersive virtual reality" (i.e., the technology used in the research here described), in a specific way, has proved to be applicable to the reproduction of road environments. Several studies have been developed in the field of cognitive psychology applied to road traffic. Some of these underline the role of perception as a part of the process that allows the driver to define the level of safety while driving [25].

1.3 Presence

Presence is one of the most important psychological constructs for understanding human-computer interac–tion. However, different terminology and operatio–nalizations of presence across fields have plagued the comparability and generalizability of results across studies. Lee's (2004) [26] unified understanding of pre–sence as a multidimensional construct made up of phy–sical, social, and self-presence, has created a unified theory of presence; nevertheless, there are still no psychometrically valid measurement instruments based on the theory [27].

There is some consensus regarding defining pre–sence as the experience or feeling of being present in a mediated environment, rather than the immediate physical environment wherein one is currently bodily present [28, 29]. However, different fields of research have typically used different terminology [26], which has made it difficult for researchers to create a unified theory of presence, thereby creating difficulties in comparing and generalizing results across studies.

Lombard and Ditton (1997) [30] identified six different explications of presence that have been used in the literature, presence as:

- social richness, the extent to which the medium is perceived as sociable, warm, sensitive, or personal when it is used to interact with other people;
- realism, the extent to which a medium can seem perceptual and/or socially realistic;
- transportation, the sensations of "you are there," "it is here," and/or "we are together";
- immersion, the extent to which the senses are engaged by the mediated environment;
- social actor within medium, the extent to which the user responds socially to a representation of a person through a medium; and
- medium as social actor, the extent to which the medium itself is perceived as a social actor (e.g., treating computers as social entities) [31].

Many studies have recorded user's subjective experience of presence and the perceived effect it has on engagement with tasks in a virtual environment [32–35].

Presence is indeed, historically, at the core of Virtual Reality (VR). Presence has often being conceived as a sign of "ecological validity" of VR devices, also as a sign of potential positive transfer of skills or knowledge learned in a VE to the real world [36].

1.4 Visual perception

Human vision is a complex phenomenon that affects the cognitive processes of driving. For this reason, it is one of the most important aspects to be considered in road safety research. It may be investigated in a real envi–ronment or in a virtual simulator: in the former case the behavior of the users is observed directly on the infrastructure; in the latter, after having designed theoretical visual stimuli, the reactions are monitored in controlled conditions.

Technological innovations have had a profound influence on how we study the sensory perception in humans. It is clear that vision research is now at cusp of a similar shift, this time driven by the use of commercially available, low-cost, high-fidelity virtual reality (VR). As such, our view of the world is rarely static; the sensory information we receive about it is constantly changing as we sample our environment in a task-dependent way [37]. Despite this, perception is rarely studied in such situations. Participants in a typical perceptual experiment are treated as passive observers of their environment. They view sparse, briefly pre–sented, reduced-cue sti–muli, from a static viewpoint, often even preventing eye movements. Because of this, there is active debate as to whether conclusions based on such artificial stimuli really reflect the way in which the visual system works [38].

Even though virtual reality (VR) systems were first investigated in the late 1960s [39], it is only in the last 10 years that has it been possible to use high-fidelity stereoscopic VR, coupled with full-body motion trac–king over large-scale volumes, to investigate perception. Using immersive VR allows experimenters to move closer to the goal of investigating human perception in a controlled and principled way, but with highly realistic stimuli that can be actively explored by experimental participants [38].

In the experimental examination of visual percep–tion, potential differences between actual and virtual reality can either be advantageous or detrimental. At the same time, higher levels of immersion and visual fide–lity afforded by VR do not necessarily evoke presence or elicit a "realistic" psychological response [40]. The use of VR brings into focus core debates about human perception and offers novel and unique ways in which to address them [41].

A common feature is the introduction of stereo–scopic depth, which creates the illusion that the viewer is seeing objects in a virtual space [42]. This offers a number of immediate advantages to the researcher: greater control over stimulus presentation, variety in response options, and potentially increased ecological validity [43]. The most apparent advantage of VR is the ability to present stimuli in three dimensions. This offers specific benefits depending on the research domain, for example, when discussing the potential application of VR to neuropsychological research [44].

1.5 The goal

Bearing in mind that driving a vehicle is critical and one of the most common daily tasks, the study addresses driver experience by employing new virtual reality technologies. Moreover, the research intends to assess the capacity of drivers to adapt their behavior according to environmental changes, which poses introduction of virtual 3D crosswalk and Road Bumpers. The main goal of the research was to appraise the relationship between the human behavior and the road geometry. The paper discusses the mechanisms based on visual stimuli that influence driver behavior and, subsequently, vehicle speed, i.e., speed selection among drivers using VR, and finally, how well does perception in virtual environments correspond to the perception in the real environment.

2. METHODOLOGY

The experiment was performed to explore how driver perception and behavior are influenced by two virtual 3D shapes projections - 3D alternative crosswalk patterns and triangular 3D markings - speed bumps (comprised from triangular prisms). In this experiment, Virtual reality headset was used to observe the stimuli (3D road markings (Fig. 1)) aiming to establish the effects they would have on subjects, willingness to reduce the speed when approaching them. All subjects volunteered to participate in this study, as well as filled out a questionnaire afterwards regarding their expe–rience with 3D simulated road markings. Sixty-three participants, 48% females and 52% males, with mean age about 30 years were involved in this study.

Figure 1. Appearance of the 3D shapes projections used in the experiment

2.1 Experimental protocol

The participants were briefed about the experimental procedure. Each subject undergoes a preliminary 2-minutes trial. This is necessary to create a relationship between the subject and the VR environment. The experiment consists of two steps. In the first one the visual stimuli placed along the road were presented and observed in order to make the assessments. The visual stimuli to which the respondents were exposed were 3D horizontal road markings (crosswalk pattern and speed bumps). Pedestrian crossing is painted as 3D optical illusion which appears like "real" three dimensional object placed on the road. The "fake" speed humps appeared as 3D barriers to oncoming traffic although the road is completely flat. The evaluation was performed in the virtual environment, where the respondents were wearing Virtual Reality Headset for the Android Smartphone with adjustable straps for flexible wear and provided with focus adjustment, as well. The characteristics of the equipment used in the experiment are presented in Tables 1 and 2.

In the second step, according to the visual perception of the presented traffic environment and their subjective feeling, the respondents gave opinions about their wil–lingness for speed reduction. Here is an example of the question forms the participants were answering: "You travel at speed of 70 km/h. During driving You en–counter an object as shown in the picture below. If You are willing to decrease the current speed of Your vehicle, enter on the line below the value on which You are going to reduce the speed (e.g., 58). If You are not ready to change your vehicle speed, type 70". The questionnaire items included also participants' demog–raphics, driving history, number of crashes, etc.

Table 1. Specification of VR Box glasses

Criteria	Characteristics
Compatibility	Mobile phones (screen size of 3.5 – 6 inches; Android, Windows and iOS platform)
Optics	33.5mm Aspheric Optical Resin Lens
Material	ABS plastics + PC Environmentally Material
Dimensions	198 x 135 x 110 mm
Weights	399 g
Other	The distance between the phone and the lens can be adjusted to suit people with different widths of the field of vision

Table 2. Specification of smartphone Huawei P10 Lite

Criteria	Characteristics
OS	Android 7.0 (Nougat)
CPU	Octa-core (4x Cortex-A53 & 4x Cortex-A53) 2100/1700/MHz
Display	LTPS IPS LCD capacitive touchscreen; 16M colors; 5.2 inches; 1080 x 1920 pixels.
Dimensions	146.5 x 72 x 7.2 mm
Weights	146 g

Preparation for experimental research required an appropriate questionnaire, the first part of which is to examine the demographic characteristics of the respon–dents, and the other to examine and collect the respon–dents' opinions on the impact of the observed 3D road markings on the driving speed. Also, it was necessary to provide the equipment and create the appropriate visual content - the representatives of 3D road markings and store them on the smartphone.

The second part of the questionnaire measured user's subjective experience of presence, i.e., the strength of presence experienced with the pictorial content presented. Each of the respondents answered each question. All participants were assigned randomly to all experimental conditions (the displayed visual content and the traveling speed).

2.2 Collecting and processing data

Statistical analysis was carried out in the statistical software package IBM SPSS Statistics v. 22. Normality of distribution was tested by inspection of histograms and the Kolmogorov-Smirnov test. Since the data for all measured variables were normally distributed, we used parametric tests. The null hypothesis that mean speed reduction values for the 3D alternative crosswalk pattern and triangular 3D markings - speed bumps are equal was tested with the Paired-Samples T-Test. To test the strength and direction of the linear relationship between willingness to reduce speed and the degree of realism of 3D shapes representations, Pearson's correlation coefficient was used.

3. RESULTS

This section provides an analysis of the experimental results in order to show the potential differences in willingness to slow down the vehicle as a response to the virtual 3D road markings.

3.1 Descriptive statistics for 3D road markings

This study aims to show how drivers' perception and behavior are influenced by two virtual 3D shapes projections - 3D alternative crosswalk pattern and speed bumps consisted of triangular prisms. The results show that the mean deceleration value is higher for 3D road marking consisted of rectangular prisms, for both test speeds (50 km/h and 70 km/h) (Figure 2.).

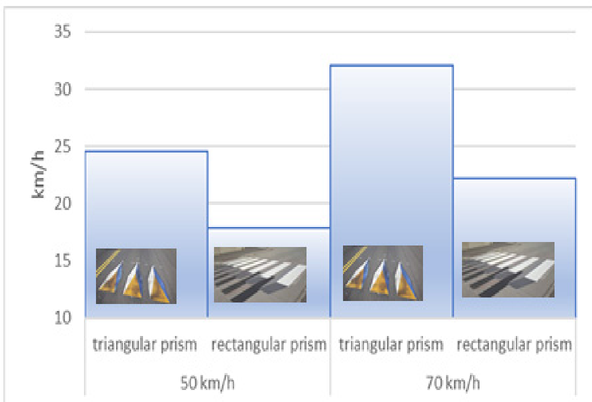

Figure 2. Mean speed reduction for 3D road markings

3.2 Willingness to reduce the traveling speed of 50 km/h

This section provides the foundation for understanding the differences in willingness to slow down the vehicle as a response to the 3D road markings for traveling speed of 50 km/h. A series of paired- T-Tests were performed to investigate whether the mean speed reduction values are statistically different. The results show statistically significant differences in willingness to slow down the vehicle for 3D road markings consisted of triangular and those of rectangular prisms (t=4.452; p=0.000). The mean speed reduction values were higher for 3D crosswalk, i.e., the respondents are more willing to reduce their speed when approaching the object consisted of rectangular prisms.

The same procedure and tests were performed for the traveling speed of 70 km/h. Again, the results show differences in willingness to slow down the vehicle as a response to the 3D road markings consisted of triangular as compared to those containing rectangular prisms (t=5.079; p=0.000). The same behavior of the respondants was observed as in the previous experiment.

3.3 Relationship between degree of realism and speed reduction for 3D road markings

The respondents evaluated the degree of realism of the 3D road markings in simulated virtual environment, ranging from 0% to 100% (0%- lack of realism, 100%- extremely realistic). The average level of presence - ratings of realism is 87.63%. There is a relationship between the level of presence - realism experienced and speed reduction for all test speeds. Drivers who reported stronger experience of reality tend to reduce their speed for more. Correlations among the degree of realism of 3D shapes and mean values of speed reduction for the cor–responding 3D road markings are presented in Table 3.

Table 3. Correlations among degree of realism of shapes and speed reduction for 3D road markings (significant value in italic if up to p<0.05)

	Reality of shapes	
	Pearson Correlation	**Sig. (2-tailed)**
triangular prism 50 km/h	*-0.553*	0.001
rectangular prism 50 km/h	*-0.43*	0.004
triangular prism 70 km/h	*-0.589*	0
rectangular prism 70 km/h	*-0.423*	0.003

4. DISSCUSION

There exists a fundamental relationship between visual perception and geometry. Points, lines, angles, surfaces, shapes, and solids constitute elementary objects of both. They are both concerned with the measurement and characterization of these elements as well as their relationships. It seems reasonable therefore that geometry would be the appropriate branch of mathematics in understanding how information is represented and processed in the visual system. Thus, the most correct explanation is obtained combining the concepts of relativity and non-Euclidian geometries in deciphering the geometry of visual perception and the underlying neural representations [45].

It is generally assumed that there are Euclidean surfaces in the visual field, and that shapes have geometrical properties replicable in computational terms. This is generally seen to be an unproblematic issue in the current computational theory of vision. Circles and squares are perceived with apparent size illusions as are areas, while cubes, prisms, cones and conical shells undergo perspectival reversal. The contours of triangles are vividly present in the total absence of any stimulus indicating such lines, arrays of triangles can spontaneously “point” as a group in a selected direction, and geometrically complete drawn parallelograms appear to be phenomenally incomplete because of 3-D interpretation of the orientation of the drawing with respect to the picture plane. To put it in more explicit terms, the space we see in is intrinsically imaginative. The main qualitative “skeletal” characteristics of this space are convexities (the space outside) and concavities (the space inside), and between these two characteristics, there may be an entire phenomenology of spatial variations [46-50].

What the subject perceives is something intrinsically qualitative and should not be compared to a Euclidean metric viewpoint or indeed even more complex spaces defined by Cayley/Klein geometries [49]. Seeing is a process where space, more than being a static sequence of planes, is bodily situated in a frame of basic egocentric directions—such as right/left, above/below, in front of/behind [51].

The visual effect of solidity is just like stereopsis in that the wire frame object appears to stick out of the paper and to be so real as to be graspable. This 3D effect takes place in the continuity of seeing, which suggests that 3D must be an ecologically dominant feature.

What occurs in seeing, in fact, is a question more of a psychic organization of qualitative contents. The visual field in seeing appears as a twofold extendedness filled with qualities at a certain location, where also the voluminous appearance of shapes is perceived more or less as such, more or less remote from the perceiver him/herself. From the observer’s viewpoint, in fact, depth is also subjective. For all these reasons, the phenomenal space of awareness has important similarities with pictorial space: one may perhaps say that they are different degrees of reality of appearances, a multidimensional simultaneity than of a set of relations and operations following the rules of formal geometry variations [52-55].

These collections of data raise the issue of a “geometry” of the purely visible, i.e., of the formal representation and modelling of what a subject perceives in actual seeing, where she/he is directly presented with appearances, not with physical objects. More than being illusory, the space of vision requires primitives and laws of organization different from the physical ones. The primitives of geometry of the visible, in fact, more often than not are imbued with connotative dimensions making them meaningful for the perceiver [51].

Observers can discriminate between a square and a rectangle when their height (or width) differs by less than 7 arc sec. This effect is seen even in the absence of a size cue, i.e. comparing shapes of different sizes does not impair performance. Sensitivity is highest for the symmetrical shapes: it is easier to judge that a shape is not a square than to judge a change in aspect ratio of a rectangle. The results suggest the existence of neuronal mechanisms tuned to aspect ratios, and that the same mechanism is used for judgments of squares and circles [56-58].

Similarly, according to the theoretical study [59], the most efficient proportions for the human eyes to scan is a rectangular shape where the horizontal is about one and a half times the vertical, which approximates to the golden ratio.

The paper describes a research, based on virtual environment surveys, aimed to better understand drivers' action-reaction mechanisms inside different scenarios, in order to gain information useful for a correct organization (design) of the road space.

Road accidents can be determined, among other reasons, by a wrong layout design. An aberration of the visual perspective and losses of visibility due to road geometry (obstacles, variations of the horizontal alignment or section, etc.) can be, together with weather and environmental aspects, the cause of inappropriate behaviors of drivers [3]. Road humps have caused debate for years, with some arguing they should be avoided because they double the amount of harmful gases emitted from cars as vehicles speed up and slow down repeatedly, including increasing in traffic noise. But road safety representatives stress their importance in keeping people safe and insist they have saved lives for decades.

5. CONCLUSION

Based on the data collected and analysed, the conclusions of this research are as follows:

- Statistically significant differences are identified in the willingness to slow down the vehicle as a response to the 3D road markings containing different geometry elements;
- Speed reduction was higher for virtual 3D crosswalk consisted of rectangular prisms;
- The degree of realism of virtual shapes is correlated with speed selection - reduction;
- Drivers who reported stronger sense of presence (more realistic experiences) tend to reduce their speed for more.

The findings can be utilized for improving driver training, but also to evaluate solutions for infrastructure design. Such conclusions should be applied in practice, so that the square-marked labels can be used at important places like school zones, kindergartens, nursing homes, etc., for a correct organization (design) of the road space, with additional benefit as a cheaper and more practical solution than a conventional approach. Besides, the results provide evidences how the road environment can really be changed in order to become more persuasive for the road users.

5.1 Further research

Virtual 3D road markings are cheaper and more practical solutions compared to conventional approa–ches. But the question arises as to when drivers become accustomed to the presence of these markings. Differences in driving behavior due to the presence of users familiar/unfamiliar with the road are commonly considered in both road design and traffic engineering. Some findings from the references confirm that route familiarity is influential on driver behavior, mainly through increasing inattention while driving [60].

As previous researchers have shown the driver familiarity with the road characteristics can have important effects on the way the roads are used. With repeated exposure, schemata and scripts allow an individual to anticipate likely events and produce appropriate responses with little or no cognitive effort. Thus, due to this habituation effect, further research is needed to investigate speed selection changes over time according to the acquired route familiarity, as well as to find ways to maintain positive changes and safe beha–viors. In order to realize this experiment in real situ–ations, it is possible to use 3D printers for the prepa–ration of 3D road markings, which are used in many areas of research [61, 62].

Due to a relatively small sample size the findings of this study should be considered provisional and as pilot results for further VR experiments using larger sample sizes, different age categories, a larger range of testing speeds and several different virtual solutions to envisage the impact of virtual 3D markings on driving behavior prior to their potential application. However, the results are relevant for the understanding the influence of geometric road design features on driver behavior, as well as, for promoting the usage of VR in the field of road safety research.

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ПЕРЦЕПЦИЈА ВИРТУЕЛНЕ 3Д ХОРИЗОНТАЛНЕ СИГНАЛИЗАЦИЈЕ – НА ПРИМЕРУ ПРОЦЕНЕ БРЗИНЕ ВОЗИЛА

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Прекорачење брзине кретања возила и лоша перцепција возача су узроци великог броја саобра–ћајних незгода. Утицај геометрије на понашање возача може се анализирати из различитих области. Обезбеђивање добре видљивости ситуација у саобраћају возачима један је од предуслова за унапређење безбедности на путевима. Уколико финансијска ситуација не дозвољава имплемен–тацију скупих саобраћајних решења, могу се наћи алтернативе у иновативним, једноставним и јефти–ним решењима. У овом раду приказано је експе–риментално истраживање перцепције 3Д хоризон–талне сигнализације (3Д пешачки прелази у облику правоугаоних и троугаоних призми) од стране возача. Резултати показују статистички значајне разлике између спремности да се смањи брзина кретања возила за наведена два пешачка прелаза у облику 3Д хоризонталне сигнализације.