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Crashworthiness analysis based on vehicle color and driver perception

Análisis de accidentabilidad en función del color del vehículo y la percepción de los conductores

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Abstract

Road safety has been of increasing concern in recent years, and vehicle crashworthiness has been highlighted as a significant challenge. While known factors such as improper driving, road conditions and driving under the influence of substances have contributed to this problem, a new perspective has emerged regarding the color of cars and its impact on crash rates. Recent research has indicated that the color of a vehicle can play an important role in road safety. The colors red, silver, white and black have been identified as those that drivers perceive most clearly in different scenarios, such as time of day, distance and traffic location.

Keywords: perception, sinister, color.

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Resumen

La seguridad vial ha sido motivo de creciente preocupación en los últimos años, y la accidentabilidad de los vehículos se ha destacado como un desafío significativo. Aunque factores conocidos como el manejo incorrecto, las condiciones de las vías y la conducción bajo la influencia de sustancias han contribuido a este problema, ha surgido una nueva perspectiva relacionada con el color de los automóviles y su impacto en la tasa de siniestros. Investigaciones recientes han señalado que el color de un vehículo puede desempeñar un papel importante en la seguridad vial. Los colores rojo, plateado, blanco y negro han sido identificados como aquellos que los conductores perciben con mayor claridad en diferentes escenarios, como horas del día, distancia y ubicación de tránsito.

Palabras clave: percepción, siniestro, color.

Introduction

Some studies were aimed at investigating the cause of traffic crashes, how to deal with them and how to prevent them. Very few studies have investigated whether vehicle color influences crash risk. In this article, the incidence of vehicle color on traffic crashes was tested, identifying a difference in crash risk with respect to color would make people make a more informed decision. Most research determined that the majority of crashes are due to inappropriate driving, poor road conditions, driving under the influence of substances (CESVI, 2021). According to research data, there is no color with a lower accident rate.

In this article, the visibility of color vehicles was analyzed through surveys to drivers and mathematical models to determine if the color implies a risk factor at the time of an accident and to inform citizens about the precautions that should be taken in this scenario. It was determined that the vehicle color with more demand at national level in the last decade; through information gathered from written sources, surveys to buyers, and in this way the guidelines by which buyers are guided at the time of choosing the color were identified. Likewise, the different perceptions that vehicle users have regarding colors in different scenarios were studied through an analysis of distance and time zone. The factors that influence buyers when choosing the color of a vehicle were identified by means of surveys and by assessing the criteria of the citizens, in order to have a direct relationship between the buyer's criteria and the color to be chosen.

A study by the University of Auckland in New Zealand indicates that vehicles with black colors have a higher accident rate, since, in contrast to silver and red colors, they have a lower percentage of vehicle collisions (Auckland, 2021). In some studies conducted in more depth on dark colors have a higher probability of accidents, since the sunlight, no matter how intense it is not able to reflect all its brightness in these colors. With this type of visual limitations, many drivers and passers-by do not see these colors in time (CESVI, 2021). Through studies conducted by the University of AUCKLAND it has been determined that dark colored vehicles have a higher accident rate than light colored vehicles; due to factors such as: sunlight and perception of the human eye do not allow a correct visualization of dark colors.

Based on results from Colombia, they determined that light colors are detected by drivers and passers-by at a distance of 200 meters before a dark vehicle (El espectador,2008).

With respect to the work published in the British medical Journal, a study published in Epidemiology in 2002 commented that it was found that yellow and white vehicles are less likely to be involved in an accident compared to vehicles of other colors (Lardelli Claret, et al., 2002). Another study conducted on the basis of documentation from public transit agencies in Australia in 2003 investigated that blue, green and gray colors are more likely to be involved in an accident than white (Newstead & D'Elia, 2007). Thus, it is known that, due to the perception of the human eye, it was investigated that vehicles with lighter colors are less likely to be involved in a traffic accident.

They were guided by the statistics made by BASF Color Report in South America, since the colors most purchased by people is white with 40%, silver with 17%, black with 10% and red with 6%, through these statistics surveys will be conducted to different people to verify the point of visual perspective of each of the drivers and pedestrians both in urban areas. (BASF Color Report). In Ecuador the trend is in line with the region in the white color as it is one of the most sold and popular at the moment, followed by the red color (El Telegrafo, 2020).

The first automobiles were painted with varnishes of natural elements and painted with brushes and brushes. These were composed of linseed oil or turpentine, in case of people with more economic power amber was used. When production of the Ford T began, the company that supplied Ford made a mixture of asphalt base, enamel and a hydrocarbon resin that made it dry much faster, also included an oven at 200 ° C and thus achieved that the paint dried in an hour.

In the mid 20's GM created and marketed nitrocellulose-based paints, from which all the colored paints of this time were derived, the only problem was that they yellowed easily. With this type of paint the spray gun began to be used.

The FIA, in order to differentiate the vehicles in the competitions, created a color code, the purpose of which was to identify the teams. The French were given the color blue, this color is distinctive of the Alpine and Bugatti teams, the French were given the color silver, the English used dark green and the Italians such as Ferrari and Alfa Romeo participated with the color red.

At the end of the 60's, alkyd resin was created in Europe, it was later mixed with melanin-formaldehyde to reduce the yellowing of light colors, with this process factories began to paint by immersion.

In the 70's premium brands developed the 2K Acryl-Polyurethane paint, this type of paint dried faster and gave greater resistance to scratches. Following this, in the 80's a layer of transparent varnish began to be used to protect the paint, which revolutionized the durability of the colors.

In the 80's the application of a coat of varnish was consolidated, this was something that revolutionized the durability of the paint, over time solvents were replaced and changed to water-based paints which is the technology currently used in the painting of vehicles.

Studies conducted by University of Dayton eCommns mentions that there are groups prone to collisions; due to the color of the vehicles, since this factor can influence the driver's visibility and thus contribute to a collision (University of Dayton eCommns, 2019). The vehicle colors with the highest crash rates are red, black, white, and silver. The vehicles representing the highest percentage of accidents are black colored vehicles figuring 15.5% i.e. 147,272 vehicles, followed by red colored vehicles with 14.9% which is equivalent to 140,869 vehicles, white 150,477 accident vehicles figuring 15.9% and finally 130,364 accident vehicles belong to the silver color category; which represents 13.7%. The aforementioned data are from accidents during the years 2011-2015 (University of Dayton eCommns, 2019).

Color is a visual perception produced in the brain due to transmission of nerve signals that are captured by photoreceptors located in the eye. In physics, color is specifically associated with electromagnetic radiation of a certain range of wavelengths visible to the human eye. Radiation of these wavelengths constitutes the part of the electromagnetic spectrum known as the visible spectrum, i.e. light. To describe color we must speak of three physical actions such as, the production of a stimulus in the form of light, which then bounces or is absorbed on a surface of an object and finally, the subjective results, such as the reception and interpretation of this stimulus in the eye, together with the brain or visual system from the object. (Sainz Cacho, 2017) Color has three attributes among these are hue, lightness and saturation. The most visible colors to the human eye are red, yellow and orange.

When talking about visibility, this refers to the human visual system. The light detected by the eyes that has been transmitted by light sources. The greatest progress in the knowledge of our vision system became possible as soon as we were able to make direct measurements on the eye receptors (Chrisment, 1998).

There are two reasons why humans have visual color deficiencies. These are innate, in other words, permanent, and having acquired it, in the latter there is a possibility of being able to remove this deficiency; this usually occurs due to disease or accidents. Much of the processing of color vision takes place at an early stage, in the retinal and NGL stages, then the signal is transmitted to the cortex where it undergoes transformations related to the color appearance of the visual stimuli. This contrasts that the shape of an object is processed first and then filled with color.

The 5 fundamental pillars of road safety are: road safety management, which aims to encourage the creation of partnerships between different agencies to create national road safety plans and strategies. Safer roads and mobility, this is more specialized in pedestrians, cyclists and motorcyclists, safer vehicles, the purpose of this is to encourage the creation and use of better technologies in the active and passive safety of the vehicle driver by means of new technologies. Safer road users and post-accident response.

Materials and methods

In this study, the inductive method was used to obtain the test values and fulfill the main objective of the article. Through the detailed and systematic observation of particular cases and the identification of recurring patterns, conclusions were drawn. This approach made it possible to discover significant trends and establish relationships between key variables. By applying the inductive method, it was possible to capture the complexity of the data collected, which provided a deeper and more contextualized understanding of the phenomenon under study. The results obtained from this approach supported and enriched the central discussion of the article, thus strengthening its contribution to the field of research.

Two complementary approaches were used, the bibliographic method and the statistical method. By means of the bibliographic method, an exhaustive review of the existing literature in the field of study was carried out. Various sources were collected and analyzed, including scientific articles and relevant papers, which provided a solid theoretical and conceptual knowledge base. This bibliographic approach provided a thorough understanding of the background and research related to this topic, as well as contextual information and previous perspectives that helped to ground and enrich the conceptual framework of the article. In addition to the bibliographic method, the statistical method was used to analyze the data collected. Statistical techniques, such as descriptive analysis, were applied to examine the relationships and patterns present in the data. Using specialized software, careful tabulation and coding of the data was carried out, which allowed us to obtain results in line with those already obtained with the bibliographic method. Rigorous statistical analysis provided solid evidence and supported the interpretation of the results, allowing us to reach reliable conclusions supported by empirical data.

Overall, the combination of the bibliographic method and the statistical method strengthened the validity and robustness of the findings obtained, providing a solid basis for the specific objectives of the article.

In this research, light SUV type vehicles were used; this type of vehicle is one of the most commercialized at the national level, since they are used for daily, family or work use inside and outside the city. In Ecuador, from January 2021 to April 2023, 44.97% of vehicles sold were SUVs (AEADE, 2023).

Through studies already conducted by BASF Color Report 2019', the Telegraph states that, in Ecuador, the trend is in line with the region: white is the most popular color followed by red and silver (El Telégrafo ,2020). A report on what have been the most popular car colors this year, and the result shows that consumers prefer cars on a monochromatic scale. The favorite color was white (38%), followed by black (19%), gray (15%) and silver (9%). Together they account for 81% of car sales worldwide. Among the remaining colors are blue (7%), red (5%), brown or beige (3%), yellow or gold (2%), green (1%) and other colors (1%) (AXALTA,2021).

Table 1: Field test in Autopista General Rumiñahui.

DATE	White	Silver	Black	Red	Orange	Win e	Blue	Celest e	Green
26/08/2022	483	459	427	438	81	68	97	16	82
27/08/2022	386	425	345	420	54	45	84	19	67
28/08/2022	429	394	356	373	64	59	79	24	76
Totals	1298	1278	1128	1231	199	172	260	59	225

The test area to determine the colors of the most predominant vehicles and those used in this article was on the General Rumiñahui Highway, a very busy area where, according to the provincial council, an estimated 70,000 vehicles pass daily.

The perception and observation test was conducted on an asphalt road in a rural area of Cayambe. This location was intentionally chosen to reduce the likelihood that the urban area and vehicular traffic could affect the results of these tests. The asphalt road provided a suitable and standardized surface for testing, which ensured equal conditions for all vehicles.

In this study, INEN 1155 was used as the main standard for this article. This standard establishes the technical requirements and specifications for vehicle lights in Ecuador, including aspects such as luminous intensity, color and proper location of the lights on the vehicle. Following this regulation ensured that vehicles comply with the established standards in terms of lighting and visibility.

This is due to the fact that there are currently no Ecuadorian standards that specifically regulate the methodology or procedure for taking tests. However, all the necessary precautions were taken to guarantee the validity and reliability of the data taken.

The ANSI Rp-1 standard was used for the data collection of the surveys, which explains the amount of luminosity that should exist in a space for the best visualization, color reproduction and contrast so that it is adequate for the specific tasks assigned.

Cronbach's Alpha method was used to evaluate the reliability of the measurement scales used in the research. Cronbach's Alpha method is a statistical scale that allows estimating the internal consistency of a set of items or questions in a scale. This was the method used because it was essential to guarantee the reliability and consistency of the measurements made in the study.

By using this method, it was possible to evaluate whether the survey items used in the data collection were consistently measuring what they were intended to measure. The calculation of Cronbach's alpha coefficient provides a numerical estimate from 0 to 1 where values closer to 1 indicate greater internal consistency in the survey.

The choice of using Cronbach's alpha method in this article was due to the need to ensure the reliability of the measurements and guarantee the validity of the results obtained.

Equation 1.

$$\alpha = \frac{k}{k-1}\left[1 - \frac{\Sigma V_i}{V_t}\right]$$

Where
α = Cronbach's alpha
k= number of items
V_i = Variance of each item
V_t = Variance of total

It is used to obtain the average of the data obtained, it is the sum of all the data and this is divided by the total of these.
Equation 2.

$$\bar{x} = \frac{\sum x_i}{N}$$

Where:
x_i = Data
N = Total data

Results

In this test, four SUVs of black, white, red and lead colors were used. A static and dynamic test was performed on a rural road near Cayambe. These shots were taken of the vehicles at 50-100-150 meters, because these are distances that can be taken both on city streets and on the highway for greater safety.

The data collection parameters are shown in Table 2 and were taken at the time of testing.

Next, we have the survey of people between 18-25 years old in a 7x4 meter room, where they were presented with the tests for 3 seconds, followed by a blank screen for them to answer the survey questions.

Table 2. *Variables*

TAKING OF PHOTOGRAPHS	
PARAMETERS	VALUE EN
Temperature	22°C
Weather	Clear
Vehicle-to-camera distance	50-100-150 m ts
Altitude	2830 masl
Location 1	C. Napo, Ayora
Time	11 am
Brightness	70000 lux

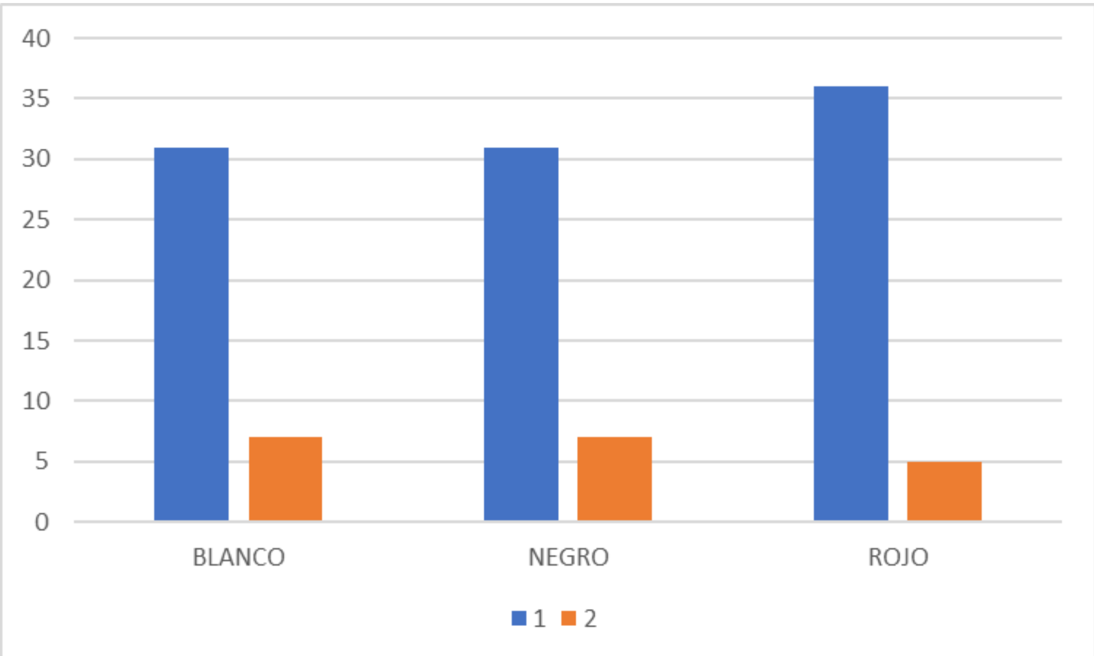
SURVEY TAKING	
PARAMETERS	VALUE EN
Number of participants per group	40
Image duration time	3 seconds
Screen size	2,1m x 1,2m
Brightness	170 Lux

In this survey, 18-25 year olds were asked to observe vehicles. The objective of this was to assess their ability to distinguish the colors and number of vehicles at different distances, they were presented with vehicles at 50, 100 and 150m meters away and asked to identify the colors of each one.

The graph presents the results of the respondents' responses to a static vehicle visualization test, where they were asked to identify the number of vehicles they could observe on the road. The graph reflects the responses collected in relation to the ability to observe vehicles at such a distance.

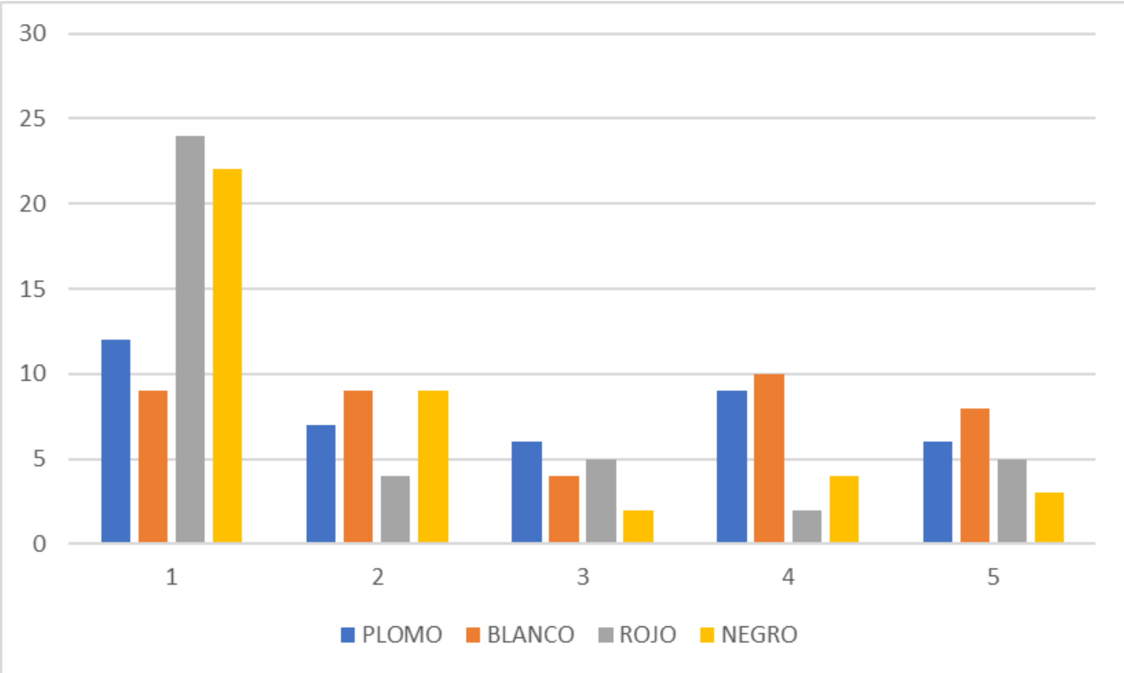
The survey results indicate that, in general, people identify cars well at a distance of 150 meters. This is important for safety, as it allows people to be aware of their surroundings and avoid potential hazards. However, there is a small percentage of people who had difficulty identifying cars at this distance, which may be due to several factors, such as poor eyesight, lack of experience or distractions.

Figure 1. Observation table for black, red and white vehicles.



This survey assessed participants' perception of flashing lights presented at 150 meters distance. Participants were asked to identify whether the flashing lights were on in each of the vehicles and to rate the perceived improvement in terms of visibility and safety when in such a situation.

Figure 2. Perception chart of lead, white, red, black vehicles.

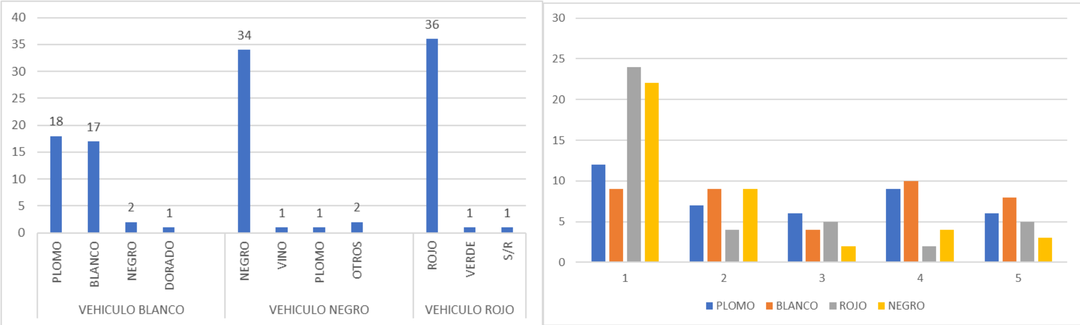


The graph presents the results of the survey of vehicle perception in static and dynamic tests of different vehicles and colors. The survey was conducted on 15-25 year olds, and the results show that the most common score for visibility in static and dynamic tests is 1. This means that most students do not find an improvement in vehicle visibility at this distance between vehicles using flashing lights and vehicles not using flashing lights at the distance of 150 meters.

The vehicle with the highest improvement in visibility in the perception test is white, followed by lead, red and black.

When comparing the results of the observation survey and the perception survey, interesting conclusions can be drawn. While the observation survey focused on the participants' ability to identify colors and number of vehicles at different distances, the perception survey focused on the participants' ability to detect and evaluate the improvement, in terms of visibility, perceived when using the flashing lights.

Figure 3. Comparative table of observation and perception of test vehicles.



It was found that in the observation tests the respondents have better visibility when identifying distant red vehicles, followed by black and finally white, taking into account that white can be confused with a lead or silver color, in this case in the response of the white vehicle there was a majority of responses of lead color being a total of 18 or 47% of responses.

In the perception tests, an improvement is noted in the dynamic tests with respect to the white color, followed by the lead color, red and finally black, which has very little improvement in its visibility.

This provided a more complete understanding of how visual perception and attention relate to the identification of vehicles and their colors in different driving conditions, thus informing road safety and the importance of visual aspects and their reactions.

Conclusions

Dark vehicles increase the probability of causing accidents, because drivers do not have a good perception of these colors at different distances; it is important to mention that the white and lead colors present in the study are those that have the lowest accident rate, the mathematical method Cronbach's alpha helps define the test reliability for perception studies, in this study this coefficient gives us a value of 0.83, this means that this has a high level of reliability, the evaluation method is highly reliable and therefore its results as well.

Based on the results obtained in the surveys conducted; it is determined that the color with the highest perception is the white vehicle, followed by the lead color vehicle, a lower visualization of the red and black color vehicle is observed, these results were obtained through the field tests already mentioned, the observation in the red vehicle is 95% this determines that this color is more visible to the driver, while the observation of the black vehicle is 89%, and of the white vehicle 45% this refers to that this color has a low visibility for the drivers. Within the studies conducted it was established that the perception has an improvement of 13.75% of visualization when the driver uses the flashing lights in the distances mentioned above, the flashing lights are a very important tool that helps drivers to the perception and visualization of vehicles either by their color or by certain distance.

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