IMPACT OF FLUORESCENT YELLOW/GREEN SIGNS ON THE PERCEPTION OF ROAD SIGNAGE: SOUTH AFRICAN EYE-TRACKING STUDY

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ABSTRACT

Road signs play a vital role in ensuring the safety of both motorists and pedestrians on roadways. They support the overall goal of creating a safer, more forgiving and self-explaining road environment. Among the various colours used for road signage, fluorescent yellow/green has emerged as an effective and attention-grabbing colour to highlight hazardous locations. Internationally, fluorescent yellow/green signage has become an indispensable tool in modern road safety efforts. However, it is currently not part of the South African Road Traffic Signs Manual (SARTSM), which is the guiding regulation for the application of road signs in South Africa. A study was conducted to measure the perception of fluorescent yellow/green (FY/G) signs using a drive lab and eye tracker to consider the measurement of the various perception variables for different genders and age groups. The results showed that the average fixation duration for the FY/G signs was higher compared to that of standard signs for all drivers, and females had a higher average fixation duration compared to males. The local and national governments can use these findings to make informed decisions regarding the implementation of standards that permit FY/G signs to be utilised.

Keywords: Road safety, Road signage, Driver perception, Fluorescent-yellow-green (FY/G) signs.

1. INTRODUCTION

The Safe System Approach (SSA), to which South Africa is a signatory, underpins the South African National Road Safety Strategy (SANRSS) aimed at substantially reducing road traffic fatalities and serious injuries. Recognising the inevitability of human error, this strategy focuses on mitigating the consequences of mistakes by designing roads, environments, vehicles, and traffic systems that are inherently more forgiving. Road signs are among the critical elements of ensuring the safety of motorists and pedestrians. International evidence highlights that "fluorescent yellow/green (FY/G)" or "safety yellow" is particularly effective in capturing attention compared to other colours used in road signage.

Fluorescent yellow/green signs have proven to be highly visible and attention-grabbing, particularly in adverse weather conditions and low-light environments, making it an ideal choice for emphasising hazardous locations and conditions (Zwahlen & Schnell, 1997). Internationally, fluorescent yellow/green signage is a prominent feature on freeways, urban streets, work zones, school zones, and pedestrian crossings, contributing significantly to road safety.

Despite its effectiveness, FY/G is not currently included in the South African Road Traffic Signs Manual (SARTSM) which is the regulatory standard for road signage in South Africa. However, given the relatively high pedestrian death rate of 45.1% of the total death toll on South African roads (RTMC, 2023), there is a need for alternative measures to highlight the plight of for example vulnerable road users in hazardous locations.

The National Road Safety Steering Committee (NRSSC) is composed of subcommittees such as the National Road Traffic Engineering Committee (NRTEC) and Road Traffic Engineering Road Safety Engineering and Road Signs Subcommittee (RSERSSC), In 2018 the RSERSSC highlighted the need to enhance the noticeability of existing Vulnerable Road User (VRU) signage, with the addition of the FY/G colour. This initiative was proposed towards reducing fatalities and injuries due to road crashes. Ultimately, the National Road Traffic Act (NRTA), Act 93 of 1996, and its Regulations prescribe road signage on South African roads.

A pilot study is necessary to test any ‘new’ road signage for a public road. The study needs to be conducted in an actual road environment and then evaluated. For a pilot study to be conducted on a public road, it needs to be approved by the Minister of Transport. Submissions to solicit approval for testing were prepared and submitted to the National Department of Transport (DoT), of which the last submission on the 19^{th} of June 2023 was titled “Proposed pilot project to enhance conspicuousness of vulnerable road user signage towards reducing vulnerable road user fatalities and serious injuries on South African roads(with the ref no: 15/18)”. The purpose of this submission was to request permission from the Minister in terms of section 56(2)1 of the National Road Traffic Act, 1996 (Act No 93 of 1996) (NRTA) for testing the use of the fluorescent yellow/green (FY/G) colour to determine whether this will enhance the noticeability of vulnerable road user signage towards reducing vulnerable road user fatalities and serious injuries on South African roads.

The aim of this research was to test impact of the FY/G signage on driver perception and behaviour. The objectives of this study were as follows:

- To assess and analyse how drivers perceive and respond to various standard signs.
- To assess and analyse how drivers perceive and respond to various FY/G signs.

2. LITERATURE REVIEW

Road signs serve as a critical component of the Safe System Approach for road safety by providing information, warnings, and guidance to road users. By effectively and uniformly communicating and managing road conditions, hazards, and regulations, road signs contribute to the overall goal of minimising the severity of road traffic crashes and improving road safety for all users.

Effective road networks depend on clear communication between infrastructure and drivers, facilitated by control elements like road markings, signs, and signals (Babic et al., 2022). These elements, particularly markings and signs, are crucial for traffic management, conveying rules and guidance for safe navigation. Their design and maintenance are essential for timely detection, readability, and comprehension (Babic et al., 2022). The perception of fluorescent yellow/green signage, often used to enhance visibility, is a complex process involving colour recognition, visibility, and driver attention.

Research has explored the impact of colour on sign detection, noting that colour-deficient drivers, particularly those with protan deficiencies, may have reduced sensitivity to certain colours like red (Sayer et al., 1999). Effective road signage is vital for safe transportation, providing drivers with essential navigational information (Castillo et al., 2019). Optimising luminance levels is also crucial for enhancing sign effectiveness and road safety (Ho et al., 2021). Fluorescent yellow/green has been explored to improve sign visibility, especially in low-light or complex environments, with some studies suggesting improved driver recognition and response times (Holick & Carlson, 2008; Carlson et al., 2017). Sufficient brightness is key for sign identification in challenging visual conditions (Ho et al., 2021).

Numerous factors influence sign detection and comprehension, including driver characteristics (age, gender, vision, background, education, psychophysical condition), environmental conditions (day/night, weather, environment complexity), and sign properties (position, retro-reflectivity, design, frequency). Luminance significantly impacts visual search efficiency, with higher levels improving visibility and reducing search times, especially for older drivers who may experience decline in sharpness of vision (Ho et al., 2001). Kwan and Mapstone (2006) highlighted that environmental factors, such as weather, road characteristics, traffic density, and visibility play a crucial role in driver perception and behaviour. They noted that although visibility aids are important, they are effective only when considering factors like road conditions, environment, and user behaviour, emphasising that detection doesn't always equal hazard recognition.

While FY/G signs are intended to improve safety, the mechanisms by which they influence driver perception and decision-making require further investigation. The FY/G signs were introduced in 1998 for pedestrian, bicycle, and school warnings to enhance visibility and improve driver reaction time (Clark et al., 1996; Burns & Donahue, 2001). Engineering research suggests that fluorescent-retroreflective signage contributes to safer driver behaviour. High visibility and ability to grab attention are essential for effective road signs (Kuniecki et al., 2015; Holick & Carlson, 2008). Fluorescent colours enhance contrast and visibility, particularly in low-light or complex backgrounds. Eye-tracking studies indicate that FY/G signs attract the driver's gaze and elicit faster response times (Holick & Carlson, 2008). Clark et al. (1996) found that these signs improved pedestrian safety marginally in daylight and showed promise in low-light conditions. Their research also demonstrated significantly higher noticeability ratings and increased driver alertness associated with FY/G signs compared to standard yellow ones (Clark et al., 1996). Schnell et al. (2001) found that while fluorescence can increase detection distances, its impact on legibility distance is less pronounced.

Fluorescent yellow/green signs may also influence visual attention and information processing. Eye-tracking studies suggest that drivers fixate on these signs longer, indicating more intensive processing. This can be beneficial in complex driving environments by reducing cognitive load and improving safety. Schnell et al. (2001) investigated various sign background colours, including “fluorescent yellow” and FY/G, finding that specific fluorescent colours improved legibility distance, likely due to increased luminance contrast. These findings have important road safety implications. Enhanced noticeability and visibility may lead to improved driver recognition, faster response times, and better decision-making. Fluorescent colours can be more effective at attracting attention, especially in low-light conditions, and are better detected and recognised in peripheral vision (Schnell et al., 2001).

Fluorescent yellow/green signage is highly visible, especially in low light conditions, adverse weather (rain, fog, snow), and during dawn or dusk. Research consistently demonstrates that fluorescent colours are more noticeable than standard reflective signs (Tomkinson & Stammers, 2000). Fluorescent yellow/green signs are easily discernible even from a distance, ensuring that critical information is conveyed to drivers and pedestrians promptly. They are particularly effective in catching the eye, leading to quicker detection and comprehension of road signage (Dutt et al., 1997). The FY/G signs improve visibility by standing out from the background, making them highly noticeable and reducing the risk of drivers missing important warnings or instructions.

Studies have shown that drivers have significantly shorter reaction times when encountering fluorescent yellow/green signs compared to non-fluorescent signs. Drivers and pedestrians react more swiftly to FY/G signs, leading to better decision-making and potentially preventing accidents. This can be crucial in critical situations, helping drivers make timely decisions (Schnell et al., 2001).

Eye tracking is a valuable tool for studying driver visual behaviour (Hurtado et al., 2016; Vetturi et al., 2019) and measuring fixations and gazes. Cvahte & Topolšek (2019) reviewed the use of eye tracking in driver distraction research, highlighting the need for studies in realistic driving conditions and emphasising the importance of visual attention for safe driving. They suggest that the effectiveness of FY/G signage may depend on its ability to capture attention amidst distractions.

Ultimately, clear communication between road infrastructure and drivers is essential for safe traffic flow. While colour plays a significant role in sign detection and recognition, broader environmental and behavioural factors must also be considered for effective road signage design and enhanced driver awareness (Ho et al., 2021).

3. METHODOLOGY

The research employed a mixed-method approach, integrating both qualitative and quantitative methodologies to ensure a comprehensive understanding of the impact of FY/G signage. A literature review was conducted to establish a foundation for the study by compiling relevant information on the application of FY/G signs both internationally and locally. Furthermore, primary data collection was conducted by collecting video data of the driving experiment and collecting survey data.

An application was developed to map and document descriptive information for both the standard signage, as specified in the South African Road Traffic Signs Manual (SARTSM), and the newly introduced FY/G signage. This application aided in organising and analysing the collected data systematically. The standard signs along the Ring Road included pedestrian crossing, speed hump - advisory speed limit, traffic circle, yield sign, yield to pedestrians, yield at the roundabout, speed limit, bus stop, stop sign, danger plate with speed hump, winding road, and wild animals sign. The twelve FY/G signs which were placed along the road include: cyclist, pedestrian, construction, and children crossing signs.

The analysis of captured data consisted of two parts: the analysis of the video data of the drives which was obtained using eye-tracking technology, and the analysis of the survey data, which supported the research. The video data of the drives was analysed using Elan software, an open-source software used to annotate and transcribe audio and video recordings. Then the videos were coded, and the data was analysed.

4. DATA COLLECTION

4.1 Data Collection

For data collection, a convenient sampling strategy was employed. Both external and internal stakeholders were invited to participate in the study. Participants were selected to represent a range of age groups (18-30 years, 31-40 years, 41-50 years, 51-60 years, and 60 years or older) and included both male and female drivers. A total of 28 participants, representing diverse demographics and driving experience levels, drove along a designated 2.4 km ring road. After completing the drives, participants responded to an electronic survey capturing demographic information, driving experience, and their perceptions of road signage. Each participant undertook two drives: the first with only standard signage (FY/G signs covered) and the second with both standard and FY/G signage visible. Both drives followed the same route, starting and ending at the same points and maintaining the same direction. To ensure anonymity and data protection, no personal information was collected. Participants were assigned numbers, and data analysis used anonymised identifiers.

AppSheet was used to develop an online platform to map and capture descriptive information on the Standard Signage (as per SARTSM) along the 2.4 km ring road of the CSIR Pretoria campus as shown in Figure 1.

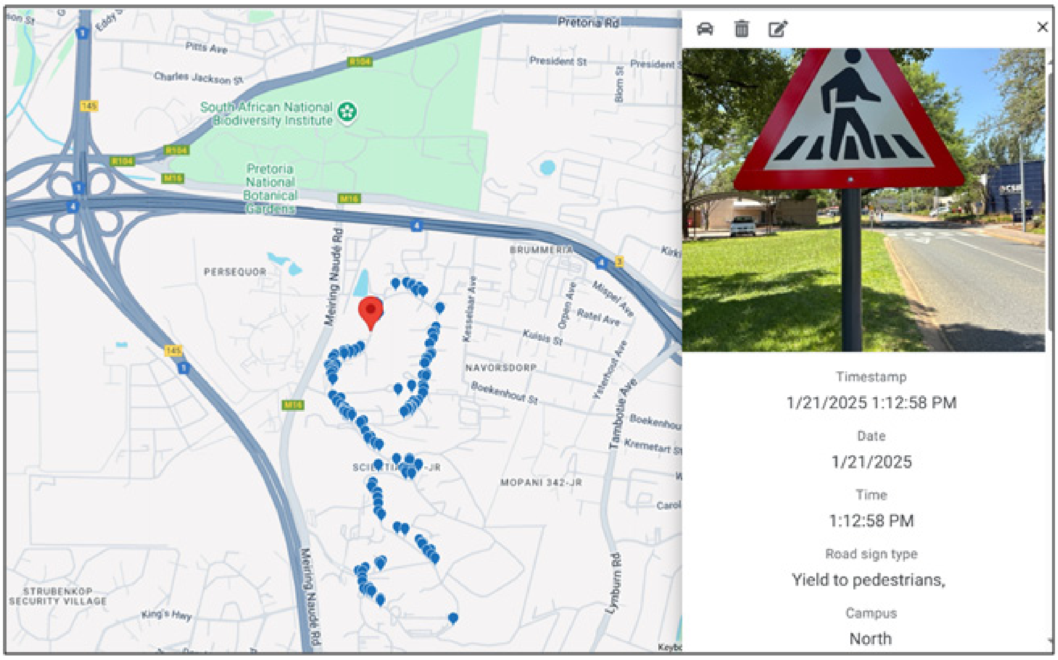

Figure 1: Mapping outputs

The study leveraged advanced technologies i.e., the Noldus DriveLab system as shown in Figure 2. This system integrated observation equipment within a real vehicle (HAVAL) to enable naturalistic driving observations. Using two cameras and an eye tracker, the system captured multiple data streams synchronised with the vehicle's operations. However, it should be noted that calibration, environment and unique eye-movements of the subjects may have influenced the accuracy of eye-tracking technology. Finally, data integration and analysis were performed using Elan software which allowed for a detailed examination of the collected data, facilitating insights into the effectiveness and impact of FY/G signage on driver perception and behaviour.

Figure 2: Noldus eye-tracking technology

4.2 Characteristics of the Respondents

A total of 28 participants participated in this survey. However, due to poor-quality videos, four of the participants were removed from the analysis. A total of 24 participants were therefore included in the analysis.

4.2.1 Gender and Age

Figure 3 shows the gender split of the driver participants for the study. The drivers were composed of 67.0% males and 33.0% females out of a pool of 24 participants. The drivers were mostly employees of the Science and Engineering research organisation. Furthermore, some of the industry partners that were included as participants were mainly from the local roads and transportation authorities. Figure 4 shows that the most represented age group was 31 to 40 years, with 54.2% of the drivers being within this age range. The second most predominant groups are 18 to 30 years and 51 to 60 years, with 12.5% of the drivers contributing to each of the groups. The least represented group was 70+ years with only one participant, holding 4.4% of the contribution to the study. This is out of 24 full participants.

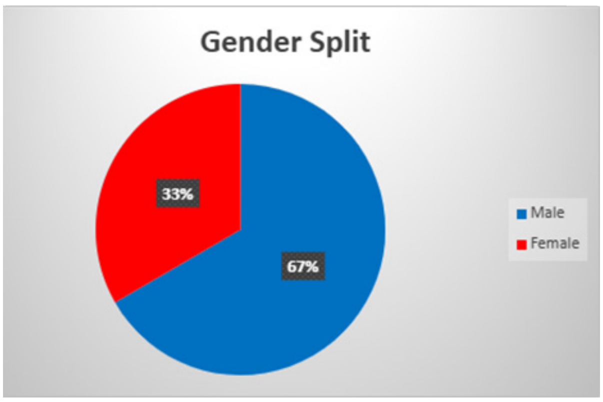

Figure 3: Gender split

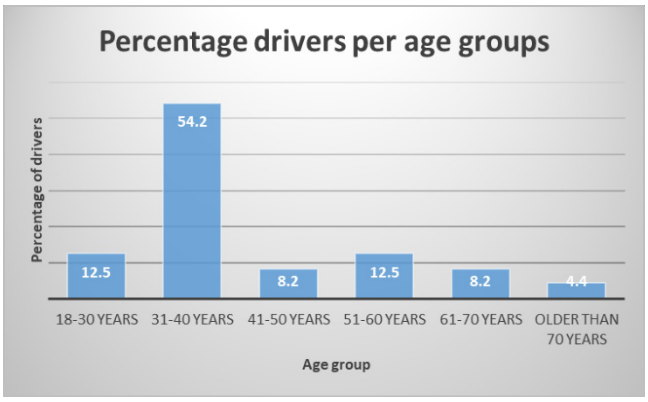

Figure 4: Drivers per age group

4.2.2 Driver's Licence Age and Driving Frequency

Figure 5 shows a bar graph distribution of drivers based on the duration of their driver's license ownership. More than 50.0% of the drivers have had their driver's licenses for more than 15 years, of which 29.1% of drivers have had their driver's licenses for more than 20 years (this indicates a significant proportion of experienced drivers in the study).

The rest of the drivers have had driver's licenses for less than 15 years. Furthermore, about 54.2% of drivers have had their licenses between 5 and 20 years, with relatively even distribution across the 5-10 years (16.7%), 10-15 years (16.7%), and 15-20 years (20.8%) categories. Only 4.2% of drivers have had their licenses for less than three years. Figure 6 shows the bar graph of the normal driving frequency of the participants outside of this experimental period. About 87.5% of the drivers reported driving daily, whilst 12.5% indicated that they drive at least once a week. None of the drivers indicated at least driving once in two weeks or once a month.

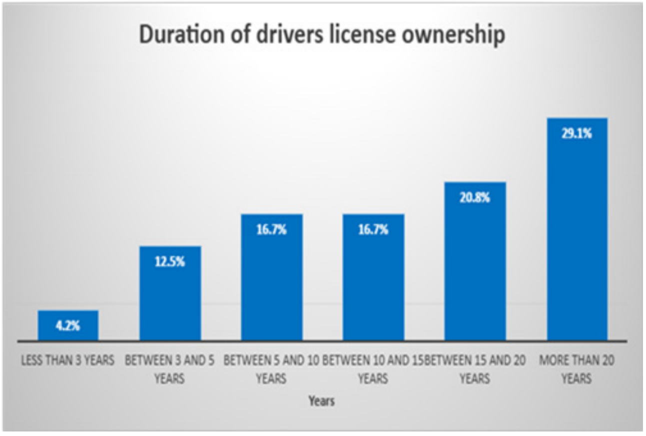

Figure 5: Driver's license ownership duration

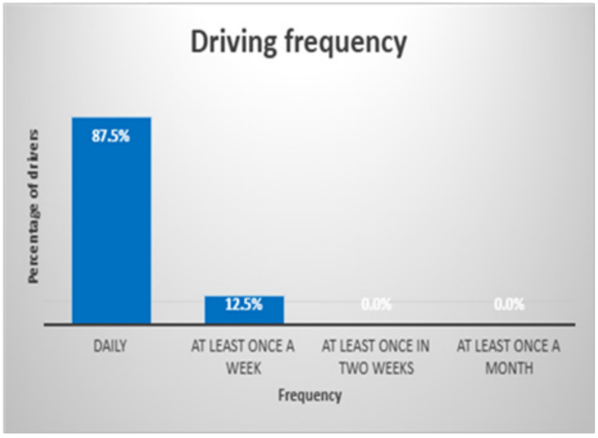

Figure 6: Driving frequency

4.2.3 Driver Perception of Signs

Figure 7 shows an equal distribution of 41.7% of drivers admitting that they recognise the signs "ALWAYS" and "OFTEN". While 16.6% of drivers stated that they only recognise signs sometimes and none of the drivers admitted to rarely recognising the signs. The type of signs that most drivers recognised were mainly composed of warning and speed limiting signs/regulatory signs, which may be attributed to the colours of the signs. Figure 8 shows that 70.8% of the drivers find it easy to comprehend the information displayed on the traditional signs, whilst 29.2% stated that it was somewhat easy to read the information.

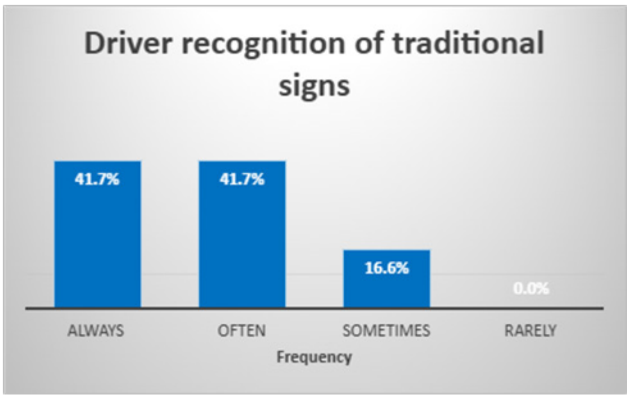

Figure 7: Driver recognition of traditional signs

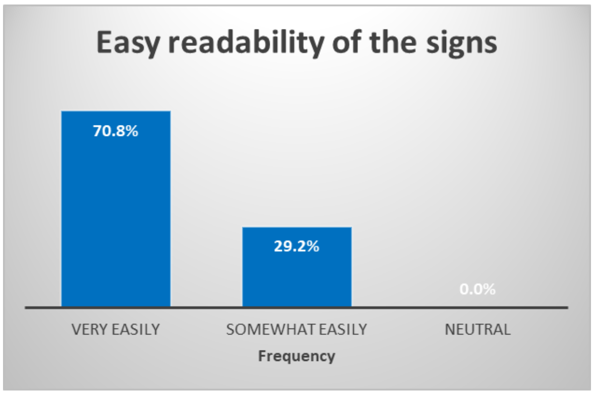

Figure 8: Readability of signs by drivers

4.2.4 Driver Awareness of Fluorescent Signs

Figure 9 shows that about 91.7% of the drivers admitted to having some knowledge about the fluorescent signs, leaving only 8.3% of the drivers who had no awareness/knowledge of the fluorescent signs (the large percentage of drivers who were aware and had some pre-knowledge about fluorescent signs could be attributed to the fact that most of the participants were from the fields of roads and transportation, and international travel experience of drivers who may have visited countries that utilise fluorescent signs). Figure 10 shows that 79.2% of the drivers reported that they noticed the FY/G signs while driving around the ring road chosen for the study (this percentage includes the portion of the drivers who had no prior awareness or knowledge of fluorescent signs).

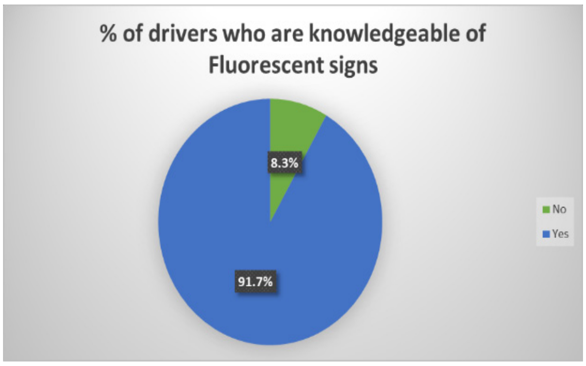

Figure 9: Knowledge of FY/G signs

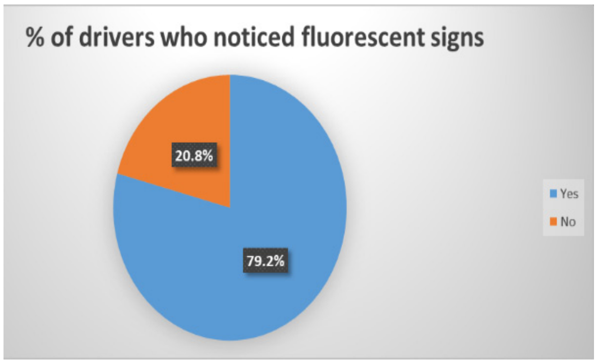

Figure 10: Drivers who noticed the FY/G signs

5. RESULTS

The average glance and fixation duration were calculated. A glance was defined as a brief, quick look at a road sign of one second and less, while fixation represents a prolonged look of more than one second. The averages were analysed according to gender and age group.

Comparing standard road signs to FY/G signs (Figure 11), the latter consistently resulted in a slightly longer glance and fixation durations, suggesting that the high-visibility colour enhances sign engagement. The increased fixation time associated with FY/G signs may indicate improved readability and comprehension, which could contribute to enhanced road safety. The average glance duration for the whole sample was 0.21 seconds for standard signs and 0.24 seconds for FY/G signs. The fixation duration was 2.17 seconds for standard signs and 2.64 seconds for the FY/G signs.

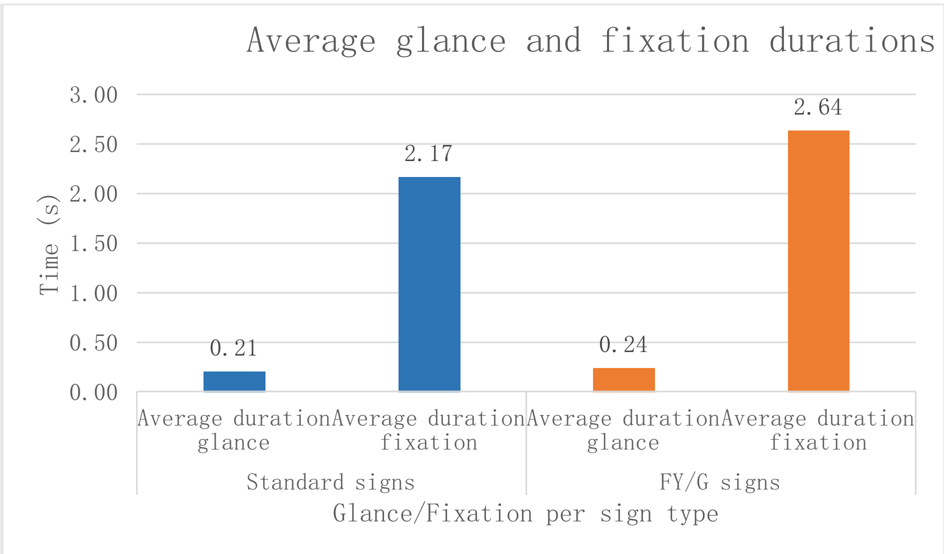

Figure 11: Average glance and durations per sign type

As highlighted above, the FY/G sign's glance and fixation durations were relatively higher than those of standard signs. However, females had relatively higher glance and fixation durations than males as shown in Figures 12 and 13. The average glance duration for males was lower than the overall average, whilst that for females was higher. However, the average fixation durations for standard signs for females were relatively lower than the overall average, whilst for males it was higher.

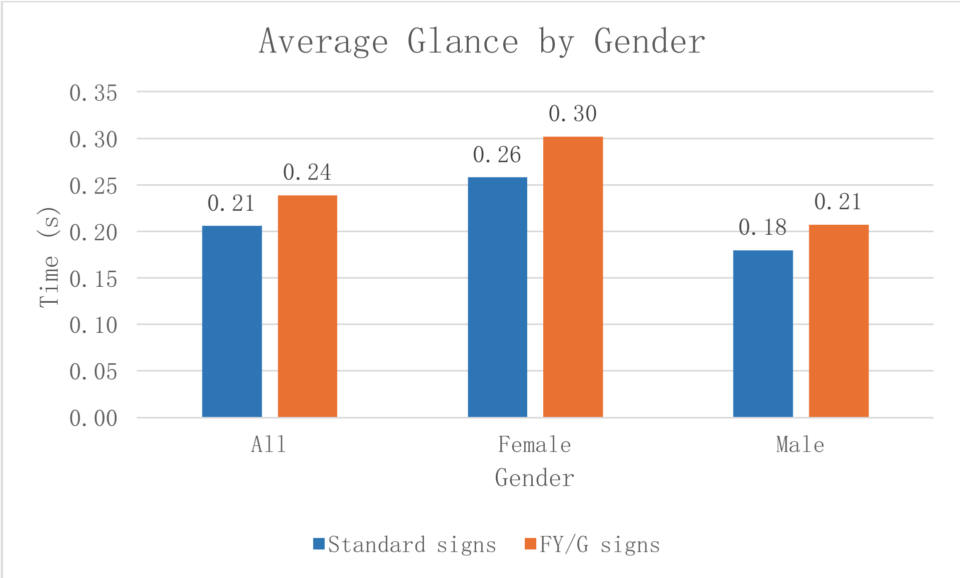

Figure 12 Average glance by gender

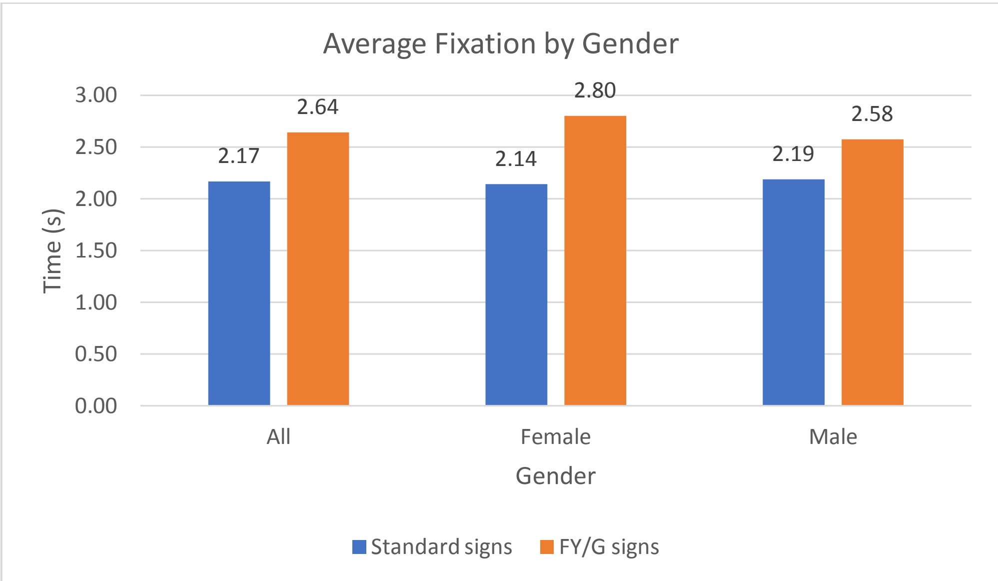

Figure 13: Average fixation by gender

The analysis of glance and fixation durations across different age groups provided valuable insights into how drivers interacted with standard road signs compared to FY/G signs. Figures 14 and 15 show that the 41–50-year-old age group exhibited the longest glance durations, particularly when viewing FY/G signs, suggesting that these signs attracted their attention more effectively while the oldest group (70+) exhibit minimal engagement, possibly due to age-related visual or cognitive decline (both groups did not fixate on any sign). The rest of the age group, though their glance and fixation durations were lower than the 41-50-year-old age group, still showed the same trend, where the fixation and glance durations were higher for FY/G signs compared to standard signs.

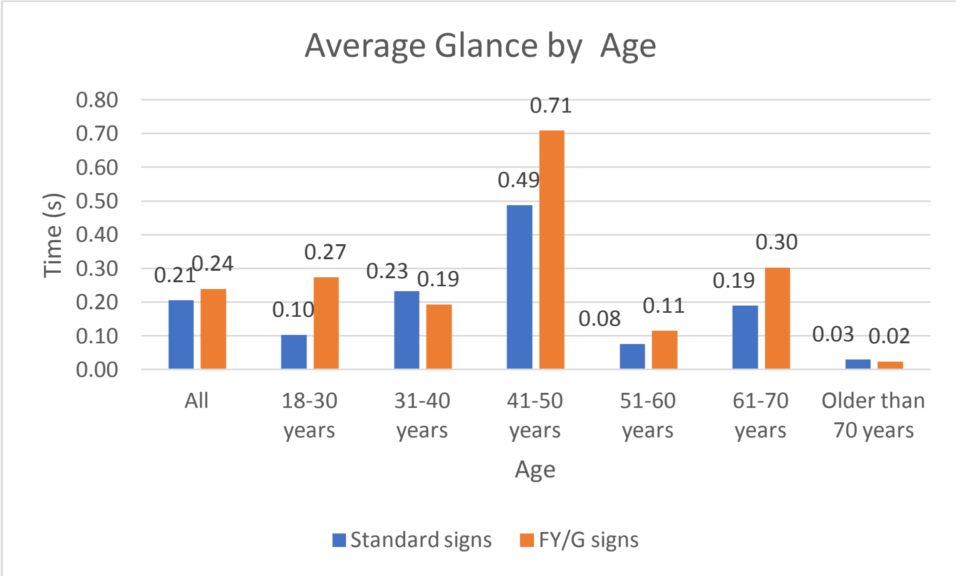

Figure 14: Average glance by age

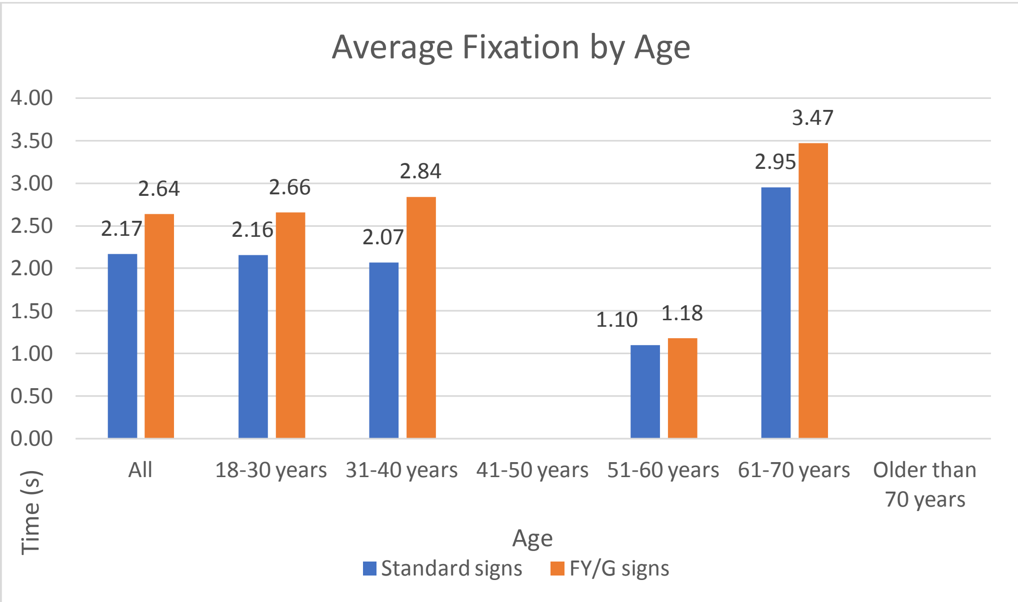

Figure 15: Average fixation by age

6. CONCLUSIONS

The research aimed to measure the driver perception of fluorescent yellow/green (FY/G) signs. The study was conducted using a drive lab and eye tracker to measure the various perception variables for different genders and age groups. The authors assessed how drivers perceive and respond to various standard and FY/G signs. The results were found to be in favour of FY/G signs as these signs attracted higher glance and fixation durations compared to standard signs.

The results of this study highlighted that most of the respondents noticed the FY/G signs. The FY/G signs attracted longer glance and fixation durations compared to the standard signs that are currently being used in South Africa. Females tend to glance and fixate at signs more than males, especially on the FY/G signs. Different age groups also showed varying glance and fixation durations; however, the same general trend, where fixation durations were higher than glance durations, was noted. This suggests that FY/G signs were more effective in capturing attention and maintaining visual engagement across diverse demographics. Although this research was conducted with a limited number of participants and limited driving conditions, these results are consistent with other studies and favour the recommendation of FY/G signs use in South Africa.

These results are vital for road safety policy and recommend the approval of FY/G signs on South African roads. Future research should aim at a higher number of participants and should be performed on public roads.

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