PROPER VISUAL CORRECTION AND SAFE DRIVING: THE EVIDENCE-BASED RELATIONSHIP

The results of optometric analyses are reported to discuss the relationship between adequate visual acuity, efficient state of binocularity, and other abilities required when driving. The results are also supported by the presence of substantial symptoms reported by drivers and associated with these visual performances. Experimental evidence found that the role of visual acuity related to the binocularity, particularly in presence of anisometropia, has consequences on the perception of distances in terms of speed of perception (stereo-speed). Significant correlation was also found between visual acuity and both glare sensitivity and light vision. Both eye-hand and eye-foot reaction times were measured, and the presence of limitations of the visual field was found to influence the speed of response to a visual stimulus.

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KEYWORDS

driving, road safety, visual performance, anisometropia, visual acuity (VA), glare sensitivity, glare sensitivity (VA), perception of depth, speed of perception, stereo-speed, contrast sensitivity, binocularity, chromatic perception, twilight vision, recovery after glare, field of vision, eye-hand speed, eye-foot speed, ability of spatial planning

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« Experimental evidence found that the role of visual acuity related to the binocularity, particularly in presence of anisometropia, has consequences on the perception of distances in terms of speed of perception (stereo-speed). »

In order to receive a driving license, an evaluation of visual acuity, field of view, twilight vision, glare sensitivity, contrast sensitivity, diplopia, and visual functions, which may affect the driving ability, are required. This study also implemented an evaluation of contrast sensitivity, glare recovery, sensitivity to glare and visual acuity twilight, eliminating some previous assessments for refractive state, in particular those relating to the degree of correctness of refraction, the diopter difference between the two eyes that previously would not have to exceed the three diopters, the stereoscopic effect and colour vision.
This study aimed to investigate the importance of the above criteria, evaluating the newly introduced tests and the importance of having an efficient state of binocularity through the analysis of the degree of correctness of refraction and stereoscopic sense. In addition to these evaluations, we wanted to compare these performances with some skills related to visual attention, a very important factor which affects driving behaviour.

Methodology
The activity was divided into two phases:

PHASE 1:
Analyses of visual and attention performances of 170 subjects with the usual ophthalmic correction in use by the subject, if any.

PROTOCOL:
1. Questionnaire regarding the visual and eye condition
2. Driver Behaviour Questionnaire (DBQ)
3. Measurement of the optical power of the ophthalmic correction in use, if any
4. Measurement of the required optical compensation
5. Visual acuity test (VA)
6. Glare sensitivity test (time needed to recognize a far character while the subject is glared by two light sources)
7. Test of perception of depth for far off objects (Howard-Dolman device)
8. Test of perception of depth for nearby objects (Super Stereoacuity Timed Tester)
9. Contrast sensitivity (Pelli-Robson device)
10. Stereo-speed measurement (Super Stereoacuity Timed Tester)
11. Binocularity test (Ergovision device)
12. Chromatic perception test (Ergovision device)
13. Twilight vision test (Ergovision device)
14. Measurements of the recovery after exposure to glare (Ergovision device)
15. Evaluation of the limits of the field of vision (Ergovision device)
16. Measurement of eye-hand speed (Wayne Saccadic Fixator)
17. Measurement of eye-foot speed (Wayne Saccadic Fixator)
18. Trail Making Test (TMT) on ability of spatial planning in a task of visual-motor type

PHASE 2:
Analysis of data measured after the prescription made by optometrists of the proper ophthalmic correction for a selected group of 24 subjects out of the 170 subjects of the previous phase. Points 5-18 above of the protocol were repeated with the proper ophthalmic compensation.

Sample description
Some characteristics of the sample are described in the Table 1.

Key findings
The main results are summarized here.

SYMPTOMATOLOGY
From a sample of 170 persons in possession of a driving license, about 24% of the subjects reported having difficulty seeing objects in the distance, with particular reference to road signs. Twenty-three percent (23%) reported a difference of visual acuity between the right eye and left eye. Thirty-one percent (31%) of subjects sometimes experienced the feeling of heavy and tired eyes. Even higher is the percentage of subjects for whom the lights appear dazzling or annoying (40%). Thirty-two percent (32%) experienced visual difficulty when driving

	Phase 1 (n=170)	Phase 2 (n=24)
Man	108 (63.5%)	17 (70.8%)
Age		
18 - 35	41 (24.1%)	3 (12.5%)
35 – 60	89 (52.4%)	9 (37.5%)
60 – 85	40 (23.5%)	12 (50.0%)
Use of glasses (if any)		
Sometime	35 (20.6%)	2 (8.3%)
Always	89 (52.4%)	19 (79.2%)

Table 1. Sample description

at night. Twenty-four percent (24%) said they experience visual difficulties when accelerating change of ambient lighting.

For the selected group of 24 subjects, the declared situation was even worse before the prescription of the proper ophthalmic compensation. Even if they could obtain the driving license, their visual abilities were not optimal and these limitations caused high symptom occurrence and problems when driving (Table 2).

STATE OF BINOCULARITY vs STEREO-ACUITY AND STEREO-SPEED

From the analysis of the optometric test results data, it is deduced that the visual acuity, in particular the difference in visual acuity between the two eyes, has a role on the state of binocularity with consequences on the perception of distances. The perception of distance was evaluated as stereo-acuity and depth perception using two different instruments (Super Stereoacuity Timed Tester and Howard Dolman Device). Worse values of stereo-acuity were typically measured in cases of fragile binocularity (stereo-acuity average of ~17 arcsec) than in cases of stable binocularity (stereo-acuity average of ~10 arcsec) with changes of depth perception to the typical values of the subjects with monocular vision (mean value measured for those monocles equal to 36 arcsec).

Although the stereo acuity is not improved as a result of the optical replacement with a new and appropriate prescription, it was possible to see an improvement in the binocular performance, measured by an increase of the stereo speed.

The local stereoscopic perception speed particularly was found to increase with the introduction of the appropriate correction (below the statistical significance set at 0.05), similarly as the speed of local/global stereoscopy perception (below the statistical significance set at 0.05).

VISUAL ACUITY vs GLARE SENSITIVITY AND LIGHT VISION

Visual acuity was also found to be a pre-requisite for other visual skills which are relevant when driving. A significant correlation (below the statistical significance set at 0.05) was found between visual acuity and glare sensitivity understood as the time required to recognize a character in glare condition. The subjects with visual acuity greater than or equal to 10/10 showed on average a response time equal to 1.95s, compared with the average results (2. 15 s) obtained from the subjects with visual acuity less than 10/10. The difference between these two groups with different visual acuity in terms of response time was statistically significant (below the statistical significance set at 0.05).

As proof of this result, in individuals who have changed ophthalmic compensation because the previous compensation was not adequate, the increase in visual acuity was accompanied by a reduction in response time under the glare effect, showing an average result of 1.93s after introduction of the proper prescription, in line with the values obtained for the group of people with visual acuity greater than or equal to 10/10.

As expected, even light vision was typically better in those with higher visual acuity. In cases of inadequate ophthalmic compensation, the introduction of appropriate correction resulted in a pronounced improvement in twilight visual acuity from 4/10 to 7/10 with statistically significant differences (below the statistical significance set at 0.05).

VISUAL FIELD vs REACTION TIME

The measurements showed that the visual field limitations are related to eye-hand and eye-foot reaction time, namely to the speed of response to a visual stimulus. Individuals with visual field limitations showed average eye-hand and eye-foot response times equal to 0.94s and 0.66s respectively, compared with the average values obtained from subjects without specific limitations of the visual field (0.77 and 0.56 s). Both in the case of hand-eye reaction and in the case of eye-foot reaction, the two groups of subjects with and without the field-of-view limitations showed significant statistical differences (below the statistical significance set at 0.05).

AGE DEPENDENCE

There were no substantial differences between the visual performances analyzed in the group aged 18-35 years and the same performances in the group aged 35-60 years. On the contrary, many measured values showed a statistically significant decline in the group aged between 60 and 85 years compared to the previous groups (Tab 3).

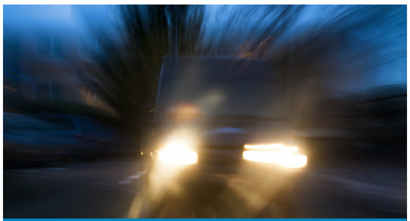
Symptoms	Phase 1 subjects (n=70)	Phase 2 (n=24) before proper ophthalmic compensation
 Dazzling and disturbing lights	40%	41%
 Difficulty to see when driving at night	32%	33%
 Heavy and tired eyes	31%	21%
 Difficulty to see at distance	24%	46%
 Difficulty in changing lighting	24%	21%
 Different vision between R/L eyes	23%	33%

Table 2. Symptomatology

	18-35 yo	35-60 yo	60-85 yo
Visual acuity	> 14/10	slightly < 14/10	10/10
Stereo acuity	10,5 sec/arc	10,5 sec/arc	13,8 sec/arc
Recovery from glare	2 sec	2 sec	2.30 sec
Local stereo speed (overt)	3.17 sec/arc per sec	2.18 sec/arc per sec	1.87 sec/arc per sec
Local/global stereo speed (overt)	3.81sec/arc per sec	2.46 sec/arc per sec	2.10 sec/arc per sec
Eye-to-hand overt reaction time	0.623 sec	0.643 sec	0.707 sec
Eye-to-foot overt reaction time	0.522 sec	0.494 sec	0.549 sec
Eye-to-hand covert reaction time	0,765 sec	0,766 sec	0,823 sec
Eye-to-foot covert reaction time	0,566 sec	0,536 sec	0,598 sec
TMT A	23 sec	23 sec	31 sec
TMT B-A	18 sec	19 sec	33 sec

Table 3. Age impact on the visual performances

The mean visual acuity of the three age groups was, in order, higher than 14/10, slightly less than 14/10, and about 10/10. The average time a subject takes to recognize a character under the glare effect rose from about 2s in the first two age intervals to 2.3s in the range 60-85 years. Stereo-acuity of the first two groups decreased in performance with age, with an increasing value from 10,5 arcsec to 13,8 arcsec in the older group.

A progressive reduction of local stereo speed was found as age increased: 3.2s, 2.2s and 1.9s, arcsec/s respectively. Similar findings were observed in the local/global stereo speed.

Eye-hand speed with overt attention shows a trend in order of time that varies from, 0.62 s, to 0.64 s, up to 0.71s. The corresponding average data in the case of covert condition were 0.77, 0.77, and 0.82s. Concerning eye-foot response, the average results were 0.52, 0.49, and 0.55s (overt), and 0.57, 0.54, and 0.60s (covert). The data of Trail-Making Tests (TMT) have also shown a clear trend in age: 23s in the first two groups and 31s in the older group for the TMT-A (capacity of visual processing) and 18s, 19s, and 33s for the TMT B-A (cognitive flexibility) (Tab. 3).

FOCUS ON APPROPRIATE OPHTHALMIC COMPENSATION

An appropriate ophthalmic correction in subjects of Phase 2 (n=24) improved visual acuity, binocularity and comfort with the following considerations:

- Increase stereopsis and/or speed in depth perception

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Giving Vision a Voice

It is widely accepted that a driver's ability to perceive visual information is fundamental to safe driving[1, 2]. Unfortunately, vision can be disrupted in a variety of challenging ways on the road, from non- or under-correction to glare. When the safety of drivers, passengers, friends, neighbors, and family depends on a driver's ability to see the world clearly, we must ensure the global conversation about vision and driving has a voice. While the United Nation's recent report on road safety did not include a discussion on vision, the dialogue on this important issue has not stopped. Many organizations and working groups around the world continue to create a significant conversation around vision standards for drivers.

The Vision Impact Institute is working diligently with its partners on research and awareness of this topic. This year alone, the organization has added twenty studies on the topic of vision and driving to the collection of research on its website. Through the systematic review process, Vision Impact Institute is identifying global gaps in this evidence with the hopes that filling these gaps will create a stronger case for necessary changes.

When studies around road safety and vision clearly show that, in an Italian drivers study, 60% of road accidents could be attributed to compromised vision[3], drivers in India with at least one visual disability have an 81% crash involvement rate[4], and in 2012, the cost of road accidents in the UK alone was more than $55 US million[5], we all have much work to do. When visual standards in driver licensing differ from country to country across Europe and state to state across the US[6], Vision Impact Institute must work to ensure policymakers take action to prioritize visual health and its role in safer driving.

We applaud those organizations and individuals, like the ones responsible for this research, who are taking bold steps to amplify this conversation. Let's continue to work together – Giving Vision a Voice!

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- Increase glare sensitivity
- Increase twilight visual acuity
- Increase response to glare

Discussion

The above results provide data to define a specific protocol to assess important visual and attention abilities that are required when driving. Specific protocol could also be developed for people involved in other specific tasks.

Conclusion

Drivers complain about visual problems related to visual acuity, binocularity and the presence of varying light conditions. The use of an appropriate ophthalmic compensation with corrective lenses is able to improve these visual abilities through the compensation of the visual defect, making binocularity faster and therefore more efficient.

European standards for obtaining a driver's license allow for better monitoring of visual acuity and visual efficiency in varying light conditions, but show less attention to the binocularity factor, especially concerning the degree of anisometropia which is tolerated.

In this respect, a new protocol of analyses and new criteria are desirable.

The above assessment also suggests the importance of eye care professionals, who can provide an adequate service for a proper evaluation of the visual performances of drivers and, more broadly, of people involved in specific tasks. •

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KEY TAKEAWAYS

- Drivers complain about visual problems related to visual acuity, binocularity and the presence of varying light conditions.

- Experimental evidence found that the role of visual acuity related to the binocularity, particularly in presence of anisometropia, has consequences on the perception of distances in terms of speed of perception (stereo-speed).

- Significant correlation was also found between visual acuity and both glare sensitivity and light vision.

- Both eye-hand and eye-foot reaction times were measured, and the presence of limitations of the visual field was found to influence the speed of response to a visual stimulus.

- The use of an appropriate ophthalmic compensation with corrective lenses is able to improve the visual abilities.

- The above assessment suggests the importance of eye care professionals, who can provide an adequate service for a proper evaluation of the visual performances of drivers.

- European standards for obtaining a driver's license allow for better monitoring of visual acuity and visual efficiency in varying light conditions, but show less attention to the binocularity factor.

- In this respect, a new protocol of analyses and new criteria are desirable.