Literature Review: Non Standard Vision Tests to Predict Functional Vision

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ABSTRACT

This literature review explores tests that demonstrate aspects of vision other than high contrast Snellen's acuity. The outcome from such tests may link to human performance in daily living tasks such as driving and mobility.

There are a variety of visual tests that demonstrate different visual skills these include night vision (Nyktotest, Mesotest, mesopic visual acuity), glare sensitivity (Mesotest, Nyktotest, brightness acuity tester [BAT]), contrast sensitivity and visual attention (useful field of vision [UFOV]). Results reported in literature suggest links between reduced performance and decreased daily living skills. For example the UFOV test is predictive of crash involvement among elderly populations. Each test will be explained and their application to driving or general mobility will be explored.

This paper raises the possibility of examining vision by using methods that will result in the practitioner being able to predict the impact of vision defects on human performance.

Keywords: functional vision, driving, night vision, mesopic vision, glare sensitivity, contrast sensitivity, useful field of vision.

INTRODUCTION

Functional Vision

Conventional clinical tests identify abnormalities such as congenital defects, refractive errors and the development of pathology. These tests include visual acuity, visual fields, ophthalmoscopy, slit lamp, intra ocular pressure, and ocular motility assessment. Some patients gain a response for all of these tests that is within the defined normal standard but may complain that their vision is not adequate for specific tasks. The tasks that patients identify include life skills such as driving at night or in glare, reading, performing occupational tasks, the recognition of faces and facial expressions, sewing and sporting activities.1 For the purpose of this paper, vision that supports life skills or quality of life will be defined as functional vision.

Functional vision can be affected by defects of the visual apparatus as well as normal environmental changes. The visual apparatus requires clear optical media; full correction of refractive error; and the full integrity of the retina, fovea, and visual pathway.[1] If there is an anomaly of any of these factors, functional vision can decline and certain visual situations may become problematic to the individual. Changes in the environment can also alter the ability to see. "We know intuitively that given the appropriate set of [atypical] circumstances each of us with 20/20 vision will function as a visually handicapped individual. Thus, when a person is driving into the sun at dusk, or dawn, changes in contrast sensitivity and the effect of glare alter detail discrimination."[2] The environmental changes often cannot be avoided but the impact on functional vision can be increased by deficits of the visual apparatus. Identification of deficits in the visual apparatus and education of the patient can assist the patients' safety and comfort.

Functional vision can be assessed with a variety of methods not used in conventional clinical practice where the emphasis is disease detection and monitoring. The methods to test functional vision fall into broad categories of vision tests (1) under different light levels (night vision and glare sensitivity), (2) contrast sensitivity tests and the (3) Useful Field of View test. (4) Personal perception of driving ability has also been strongly linked to most of the vision tests described.[3]

A review of literature has revealed a range of tests that investigate different aspects of functional vision. These will now be discussed.

1. Tests under different light levels

1.1 Night/Twilight Vision

The quality of night vision is a very important factor for functional vision because it can affect a person's ability to cope in low light situations. Such functional aspects include driving at night, walking around the house at night or in low light levels and reading in reduced light levels. In reality most night vision activities involves a low light source and might be more accurately described as twilight vision. Twilight vision is the transition from photopic vision to scotopic vision.[4] Scotopic vision uses the rods whereas photopic vision uses the cones. The area in between where both the rods and the cones are contributing towards sight is called mesopic vision.[5] If you consider driving at night; some examples of low light sources would include overhead streetlights, car lights, city lights, headlights, the moon and residual sunlight during dawn and dusk. Twilight vision would also include the situation of driving a car in the country at night, without the moon being present, where the driver would increase the intensity of their own car lights using high beam.

Twilight vision can be degraded by refractive error, ocular pathology and age related changes.[6] The pathology can include cataracts, retinitis pigmentosa, glaucoma, and vitamin A deficiency.[6] Cataract's can degrade night vision by decreasing the contrast sensitivity, increasing myopia due to the changes in the refractive index of the lens, and monocular diplopia due to light splitting.[6] Retinitis pigmentosa specifically depresses the rod function of the retina and therefore the most common symptom is a failure to see properly in dim illumination.[6] Glaucoma decreases peripheral vision which is largely rod function thus the glaucoma patient may have difficulty with how well they see at night. Vitamin A deficiency can cause night blindness because vitamin A is the main component of rhodopsin, which is essential to night vision.[6]

Twilight vision also described as mesopic vision can be tested with an array of instruments which are used around the world. Such tests include the mesopic vision test, Mesotest and Nyktotest.

1.1a Mesopic Visual Acuity or Twilight Visual Acuity

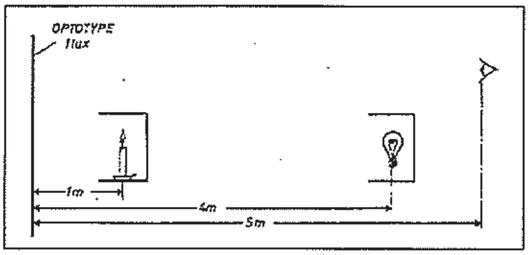

Fig 1. Set-up with stearin candle (1m) and incandescent lamp of 15W (4m) to obtain the necessary illuminance of 1 lux.[4]

Mesopic vision, which determines nighttime functional vision, can be assessed with a vision chart that has an illuminance of 1 lux. An illuminance of 1 lux can be approximately demonstrated by placing a 15-Watt light source, in a dark room, 4 metres from an optotype. An illuminance of 1 lux can also be achieved by placing a stearin candle 1 meter from an optotype.[4] Mesopic contrast vision can also be assessed using both the Mesotest and the Nyktotest. These two specific tests are mainly used in certain countries in Europe where there are laws for the minimum night vision that is required for driving. In Belgium the minimum driving standard for twilight (mesopic) vision is 6/30. Night vision decreases with increasing age and eye pathology.[7,8] It has been proven that drivers with reduced twilight vision are more frequently involved in accidents at night than those who fully satisfy the minimum requirement for visual functions.[9]

1.1b Mesotest II

Fig. 2 The Mesotest II by Oculus.[10]

The Mesotest II can assess mesopic contrast sensitivity and glare sensitivity. The patient has to identify the direction of the gap in the Landolt rings, which have an array of six positions. During the test the rings are presented in four different contrast levels. The affect that glare has on the individual is assessed by using a bright glare source pointed towards the eyes whilst performing the contrast test. The Mesotest II is especially useful when assessing a person pre/post IOL and refractive surgery. It complies with the standards for mesopic vision testing as set by the DOG (Deutsche Ophthalmologic Gesellshcaft [German Ophthalmological Society]).[11,12] Contrast sensitivity, as measured with the Mesotest, deteriorates in an age dependant fashion. Thus as contrast sensitivity decreases with age there is a logical link with reduced night driving ability. In a study by Scharwey the majority of persons over the age of 60 were not able to fulfil the criteria for night driving ability according to the recommendations of DOG.[8] The population studied revealed that nearly 40% of persons aged over 60 had reduced night driving ability.[8] A study by Rassow et al they found that even when surgically correcting a cataract with an IOL that approximately 60% of patients will not satisfy the standard for night driving as set by DOG.[7]

1.1c Nyktotest

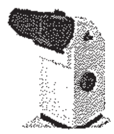

Fig. 3 The Nyktotest by Rodenstock.[13]

The Nyktotest is an instrument that tests contrast sensitivity in twilight, both with and without a bright glare source from the side. The Nyktotest is similarly configured as the Mesotest II. Both tests present a target with varying contrast levels. Again this can be used both with and without a glare source. This test helps to detect uncorrected or insufficiently corrected defective vision. It also can detect night myopia.[14,15] This test has been used in a variety of research papers investigating the pathology which affects night vision.[3,7,16-19] The Nyktotest has been recommended to be used only as a screening test because it has a lower reliability result than similarly corresponding night vision assessor's such as the Mesotest.[17] In a study by Katlun it was found that even 1 year after PRK the number of patients with reduced contrast sensitivity using the Nyktotest (with and without glare) was higher than before PRK. It is important to note that before PRK was performed there were a number of patients with decreased contrast sensitivity (both with and without glare) who did not satisfy the requirements for driving in Germany as set out by the DOG.[16]

Testing twilight vision with the following tests: mesopic visual acuity, Mesotest and Nyktotest, has revealed a greater knowledge about functional performance when driving. It also brings into focus the importance of discussing the possible impact on functional vision prior to any refractive procedures.

1.2 Glare Testing

Vision tested in the clinical setting is usually performed at optimal conditions with high contrast. A patient with a normal visual acuity standard of 6/6 can still complain of visual problems related to glare.

Cassin defines glare to be caused by a "light stimulus not near a fixation target that can raise the threshold of the macula and decrease visibility of the target."[20] Glare is produced by the scattering of light caused by an obstruction in the light's path to the macula.

There are two types of glare including discomfort glare and disability glare. Discomfort glare is defined as the sensation caused by glaring light sources.[21] Disability glare is defined as the reduced visual acuity because of stray light entering the eye (scattered light) due to a glare source.[21] Therefore, discomfort glare corresponds to a sensation, whereas disability glare considers visual function.[21]

Visual acuity can reduce considerably in the presence of bright light when there are opacities in the media. Media opacity includes cataract, corneal scar, protein particles in the anterior chamber (flare), or postoperative radial keratotomy.[20] It has been shown (P<0.0001) that with an increase in age there is a general increase in the susceptibility to glare associated with identifiable eye pathology.[22]

Disability glare can be noticeable to the person in bright sunlight, or whilst driving at night.[20] This can cause the person, who for example may be playing sport in bright sunlight, to be affected and unable to see what is happening around him or her. Driving with the low sun as a glare source can also be disruptive to a persons driving. The glare sensitive person may also experience problems whilst driving a car at night. The lights from oncoming traffic may hinder or prevent the driver from reading valuable road signs and more importantly seeing what is directly in front of the vehicle on the road. An individual with a small central cataract may be seriously affected when participating in sports and driving, due to the pupil contracting, which increases glare susceptibilty.[6]

There are a variety of glare testers on the market including the conventional Brightness Acuity Tester (BAT), the Nyktotest, Mesotest and the Straylightmeter.

1.2a Brightness acuity tester

Fig. 4 Brightness Acuity Tester by MARCO Ophthalmic, Inc[23]

The Brightness Acuity Tester (BAT) is a small device with a spherical bowl, which is placed over one eye and shines light into the eye, it has a hole which allows the user to view the vision chart. The BAT can determine significant visual loss attributed to a bright light that creates a small pupil and glare.[23] The test should be performed four times: at normal, lowest, medium and high illumination. Initially the test is performed without any other light source to test normal visual acuity. The second time it is performed with the BAT at its lowest illumination, which is equivalent to a room with normal overhead lighting. On the third occasion the BAT is performed at medium light levels, which is equivalent to being outdoors on a cloudy day. On the fourth and final time the BAT is set at its highest setting, which is equivalent to being outdoors with direct overhead sunlight.[24] No more than one line of difference should occur in patients without ocular opacities or distortions. There are three results that can be interpreted from performing the BAT. They include a response which is worse, better or has not changed. No change in acuity suggests that there are no significant ocular opacities or distortions present. An improvement in vision is associated with residual refractive error or non-central cortical cataract due to the pinhole effect associated with a constricted pupil. A decline in acuity is commonly associated with opacities in the ocular media.[20]. A deterioration in acuity due to disability glare as tested with the BAT may identify a future need for treatment.

1.2b Nyktotest and Mesotest

The Nyktotest and the Mesotest both assess glare sensitivity whilst performing a contrast sensitivity test. The Nyktotest and Mesotest are specifically designed to simulate driving conditions at night/twilight by having the patients dark adapt for 10 minutes and then measuring the contrast sensitivity, with and without a bright glare source on the side of oncoming cars. This test mimics the conditions of driving at night and has been used in an array of research papers investigating vision function when driving. It was found that glare sensitivity deteriorates with increasing age and in the presence of cataract, IOL implants[25] and PRK[16]. For these conditions glare is a problem when driving at night and causes difficulty viewing objects in the line of their sight when affected by glare.[8]

1.2c Straylightmeter

Fig. 5 The Cataract quantifier also known as the C-Quant (the new Straylightmeter).[26]

Disability glare has been directly linked to the amount of stray light that is present in the eye. The Straylightmeter measures the amount of retinal stray light in the eye, as a basic physical quantity.[27] The measurement does not rely on the patient's perception and is more objective than the Nyktotest and Mesotest. The Straylightmeter works by flashing a circular light source on and off at about 8 hertz, this is our peak flicker detection. The test is separated into two frames. One in which the stray light is on and the other in which it is off. The person is seeing two images one on top of each other in a flickering fashion. If the centre of the image is black in both frames, the subject will perceive a flicker on the fovea. This is due to light, which will only reach the fovea when the stray light is on. The centre black dot is continually watched and the patient continually increases the amount of light on the "off frame's" centre target, until they stop perceiving a flicker sensation. The amount of compensation light required on this centre target is equal to the stray light that is scattered in the eye.[21]

In a study by Van Rijn et al.[28] several contrast sensitivity tests were evaluated for repeatability, validity, and discriminative ability. The clinical assessors included conventional contrast sensitivity based tests such as the Mesotest and the Nyktotest and the non-conventional new stray light meter. The study was conducted to particularly discriminate between clinically evaluated cataract patients from non-cataract patients. The results from the study showed that the Straylightmeter was able to discriminate, between those patients who suffered with early cataracts to those who did not have any cataracts, better than the conventional contrast sensitivity based glare tests.[28]

Testing glare sensitivity with the conventional Brightness Acuity tester, the Nyktotest and Mesotest, and the Straylightmeter has revealed a greater understanding as to the importance of the impact that glare has on functional vision. Disability glare in most cases is due to opacities in the ocular media, and these tests quantitatively identify the reduction in vision under glare conditions that occurs with the associated pathology. Glare testing reveals an important area for identifying and treating the offending pathology to improve quality of life.

2. Contrast Sensitivity

Contrast sensitivity is becoming an increasingly more accurate way of measuring functional vision. Contrast sensitivity refers to the ability of the visual system to distinguish between an object and its background. Some people may complain of visual dysfunction but still achieve "normal" vision on the Snellen visual acuity chart. This is because visual acuity assesses the smallest letter that is observed at maximal contrast. However our visual world contains many low contrast visual cues that are more difficult to see should there be a deficiency in the visual mechanism. A high level of contrast sensitivity is important for the identification of objects whilst driving under certain conditions such as in fog, whilst raining, at night, or during dusk. It can also be of assistance for normal living skills and daily tasks such as reading speed or performance, mobility, perception of faces, computer work, occupation activities and sport.[29]

Contrast sensitivity can be affected by various pathology including cataracts, glaucoma, macular degeneration, retinitis pigmentosa and rod-cone dystrophy.[6, 20] To achieve a high level of contrast sensitivity full correction of ametropia is necessary, as well as a healthy visual system. The blur produced by ametropia hinders the recognition of objects.1

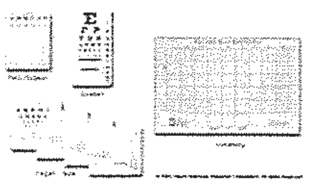

Fig. 6 Different contrast sensitivity tests including the Pelli-Robson, Snellen, Regan, and the FACT by Ginsburg.[30]

There are two ways of testing contrast sensitivity including sine-wave type tests (e.g. VISTEC and FACT); and letter charts (Pelli-Robson and Regan charts). Contrast sensitivity using sine wave gratings at different frequencies is the most sensitive method for testing contrast sensitivity.[31] The low frequencies (wide bars) tests sensitivity to very large objects whilst the higher frequencies (narrow bars) measure the sensitivity to viewing very small objects. Each test frequency starts at a high level of contrast which diminishes progressively with subsequent circles.[32] Therefore the design of the chart illustrates how well a person is able to see varying object sizes (frequency) in variable light levels (contrast).

There are two types of letter contrast sensitivity charts, including the Pelli-Robson and the Regan contrast sensitivity charts. The Pelli-Robson determines the contrast required to read large letters of a fixed size. The chart uses size 6/30 letters which decrease in contrast only.[20] This test has only a limited value because it eliminates the variable of spatial frequency. Although this test has its short comings it does have the added advantage of presenting the familiar format of a lettered chart.[33]

The Regan chart uses a standard acuity chart at different contrast levels. It includes four separate charts for absolute, high, intermediate and low contrast levels. Although this may seem like it would be the superior type of contrast sensitivity test (using letters of different sizes and contrast levels), it has been seen as time consuming to perform and converts to a person being able to perceive only the sharp edges of a scene.[30]

Driving a motor vehicle at night is a time when street signs, and other visual cues are at a very low contrast level. Ball et al, reported older drivers with a diagnosis of cataracts and macular degeneration typically avoid driving at night more than those free of ocular disease.[34] Considering these conditions reduce contrast sensitivity it is not surprising that they restrict themselves to driving only in high contrast situations. Contrast sensitivity is a useful tool in assessing a person's function vision during the night and under low light level situations.

3. Useful field of View

The Useful Field of View (UFOV) is a computerised product developed in the United States of America that evaluates visual attention under a variety of cognitive demands. The test is designed to calculate the visual field area over which a driver can process rapidly presented visual information. This test has been incorporated into studies examining the relationship between aging, cognitive decline, and driving ability. It is also able to predict the possibility of the future likelihood of crashes by an individual.[35] The test is particularly relevant when determining the possibility of crash occurrences by older drivers,[36-38] or those affected by multiple sclerosis.[35]

The UFOV is conducted by subjecting the candidate to a series of sub-tests. The first is a Visual Information Processing test, the second is a divided attention test and the final is a selective attention sub-test.

The sub-tests are performed by presenting the candidate with a simple object which they can relate to, such as a car or a truck. Objects must be identified by the candidate after a brief exposure to the shape. As distracting visual stimuli is added, the tasks become increasingly more complicated. The sub-tests allow the examiner to develop individual performance scores, which are measured in milliseconds. This allows a tester to determine the length of time required by the candidate to process information accurately. The performance score, an essential measure of this temporal latency, indicates that a high score relates to poor performance by the candidate, which suggests that the candidate is more likely to have impaired driving ability.[35]

Owsley[37] investigated a large group of older drivers for eye health, visual sensory function, the size of the UFOV, and their cognitive status. The participants were stratified using age and crash frequency. This research found that those individuals "with visual sensory impairment, cognitive impairment, and/or a constriction in the size of the useful field of vision were at a greater risk for crashes than were those without these problems."[37]

The UFOV is a useful and new approach to assessing vision and its impact on driving ability. This test is a break away from the traditional measurement of visual sensory function, because the UFOV encompasses perceptual and behavioural aspects to assess visual function with a strong influence on driving ability and crash rate. The computer operated software is available in Australia on a user pay basis. It is not endorsed by the Drivers License Authority in Australia.

4. Personal Perception (Perceived Driving Disability)

One method of detecting functional vision is to examine the personal perception of visual ability via a questionnaire. The Perceived Driving Disability assessment is a questionnaire specifically designed to give a score on how a person perceives a certain situation when driving.[3] Situations that are included in the questionnaire are perceived driving disability at night and perceived driving disability in unfamiliar places. Perceived driving disability at night was calculated by subtracting daytime scores from nighttime driving question scores. The perceived driving disability in unfamiliar places was calculated by subtracting the scores of driving in familiar places from those in unfamiliar places.

Van Rijn et al[3] performed a study in which he used this questionnaire's responses and different visual assessments to find out the relationship between a persons perception of driving disability and the scores on the vision screening tests. Vision tests that were used in the study by Van Rijn et al[3] included visual acuity, contrast sensitivity (Pelli-Robson chart), visual field (HVF analyser), mesopic contrast sensitivity and glare sensitivity (Mesotest II and Nykotest 300).

The perceived disability when driving at night and in bad weather conditions, were found to specifically relate to the scores on the Nyktotests and the Mesotests. This is particularly evident in subjects with "good" visual acuity (6/7.5 or better). Although visual acuity indicates how well a person can see, it does it only in the sense of a high contrast environment. Outside the clinical environment, the visual world is bombarded with low contrast objects. When the perceived driving disability questionnaire was compared to clinical responses, it clearly demonstrated the importance of alternative visual assessments for drivers. In this study no correlation was found between perceived driving disability at night and visual acuity scores for near and distance. Whilst not a formal clinical test personal perception provides excellent feedback about driver coping skills.

CONCLUSION

Functional vision is an exceedingly broad and yet highly documented area. A number of non-standard vision tests are available which when combined with conventional clinical tests are able to provide a better understanding of a patient's ability to see under different conditions.

The Mesotest II and Nyktotest can assess mesopic contrast sensitivity and glare sensitivity. These tests are useful in determining a patient's ability to recognise objects at night and under glare situations. The mesopic Visual Acuity test can also provide valuable data of how well a patient can see under night or twilight conditions. These tests are mainly used in Europe where there are legally enforceable nighttime driving standards. However currently in Australia there are no such driving standards in place.

Glare testing methods such as the Brightness acuity tester and Straylightmeter can offer a valuable insight into how a patient responds in a high glare situation. This is important to recognise as this can be potentially missed during standard clinical tests. Our ability to measure how a patient is able to respond to glare is important, as glare has been found to significantly hinder a patient's ability to see under relevant light conditions. Additionally the Mesotest and Nyktotest test can also be used to provide glare data on a patient. The main reason for experiencing glare susceptibility and its impact on vision is due to opacities in the ocular media. Thereby indicating a need to identify and treat these pathologies early.

Contrast Sensitivity is useful in testing patients in the clinical environment to explain why they are complaining of visual difficulties despite normal visual acuity. This test allows the clinician to determine exactly how the patient is affected by their declining optical media.

The Useful Field of View determines a driver's ability to observe and comprehend the busy visual situations that the driver is assaulted with when driving a motor vehicle. The result from this test has been matched with crash rate. This is a useful tool because it encompasses visual function and cognitive ability with a strong impact for crash rate whilst driving.

Finally questionnaires such as the Perceived Driving Disability questionnaire can provide a score, which was designed to determine how a person perceives a certain situation whilst driving. The results of this correspond to the patient's results on certain clinical tests versus the patients perceived ability to see.

Vision under ideal clinical conditions does not provide the full story of how an individual copes in real life. A range of tests are available that examine patient skills in different light levels and environmental circumstances that can better inform the practitioner of the patients ability to cope in life. Recommendations can then be made on adapting to certain conditions or to intervene with specific treatment.

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