Static and Dynamic Visual Acuity Assessment in Ophthalmological Practice

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Summary. Static visual acuity is the ability to see clearly in a nonmoving position and looking at a nonmoving object. Static visual acuity test measures impairments in visual resolution that can be caused by blurring of the retinal image, neural processing disorders, or damage to neurons in the retina or other parts of the visual pathway.

Dynamic visual acuity refers to the ability to resolve a target visually when there is relative motion between the target and the observer. Currently, dynamic visual acuity is mainly applied to investigate visual function related to elite sportsmen performance and driving safety. Dynamic vision is becoming an essential part of studies on the effects of aging on vision. It has been confirmed that there is severe degradation in dynamic visual acuity performance with increasing age after approximately the fourth decade of life. In clinical medicine, dynamic visual acuity has not been widely used.

In this article, we review static and dynamic visual acuity assessment tests ant their value in ophthalmological practice.

Keywords: static visual acuity, dynamic visual acuity, ophthalmology.

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INTRODUCTION

Vision is a complex sensation that provides a personal representation of an individual's surrounding environment [1]. Visual acuity is the simplest method, which is most commonly used by ophthalmologists to examine the function of vision. Static visual acuity (SVA) is the ability to see clearly in a nonmoving position and looking at a nonmoving object. SVA tests measure impairments in visual resolution that can be caused by blurring of the retinal image, neural processing disorders, or damage to neurons in the retina or other parts of the visual pathway [1]. Optical and neuron degenerative changes of visual system that influence the steady decrease of visual acuity are observed from approximately 40 years of age [2]. With aging, people's vision becomes less clear; big objects can be seen clearly but problems occur when people try to discern minor things and minor details. Additionally, senile miosis is developing, the eye lenses are becoming less clear, stiffer, and the accommodation and convergence reserves are starting to decrease [2]. These changes reduce the access of light to the retina. It is estimated that more than 150 million people in the U.S. general population have visual impairment caused by refractive error, other relatively common disease-related causes of visual impairment include age-related macular degeneration, cataracts, diabetic retinopathy, and glaucoma. The number of people with vision impairment from age-related eye disease is expected to double in the next three decades [3].

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The static visual acuity provides only limited information about functional vision, that's why for detailed examination we need to evaluate dynamic visual acuity (DVA). A number of studies analyzing DVA showed that dynamic acuity declines with age or progression of eye diseases [4, 5]. DVA is becoming an essential part of studies on the effects of aging on vision. It has been confirmed that there is severe degradation in DVA with increasing age after approximately the fourth decade of life.

In this article, we provide the latest literature review about the assessment of static and dynamic visual acuity ant their value in ophthalmological practice.

WHAT IS STATIC VISUAL ACUITY?

The visual world in which we live contains both static and dynamic components [6]. As such, the visual system has developed to respond to a wide variety of stimuli [6]. In clinical practice doctors pay attention to foveal visual acuity.

SVA is the ability to see clearly in a nonmoving position and looking at a nonmoving object. SVA declines rapidly with increasing eccentricity from the fovea in a symmetrical fashion in both the nasal and temporal visual fields out to an eccentricity of approximately [7]. Beyond this, SVA is better in the temporal visual field than in the nasal visual field [7]. These differences have been attributed to lateral asymmetry of retinal ganglion cells beyond the optic nerve head [8]. SVA test measures impairments in visual resolution that can be caused by blurring of the retinal image, neural processing disorders, or damage to neurons in the retina or other parts of the visual pathway [8]. Visual acuity is the simplest method, which is most commonly used by ophthalmologists to examine the function of vision. An optotype chart, which contains 12 rows of signs (letters, numbers, rings with a gap, drawings of various objects) (from 0.1 to 1.5), is mostly used for visual acuity examination. According to Snellen, visual acuity can be expressed in spatial frequencies, however, the highest spatial frequencies are evaluated by standard visual acuity test only upon the condition of maximum contrast (V=1.0 match 30 cycle/degree when contrast 100%). The Snellen chart provides limited information about functional vision [9]. Functional or "practical" vision is described as our day-to-day vision – what we see and how we process this information [10]. Regular Snellen's eye chart allows to evaluate patients' ability to determine black letters on a white background from the distance but it does not show the visual quality [9]. The test is administered in a standardized way, using visual acuity optotypes illuminated on a light box, resulting in quantitative visual acuity test results. Snellen's original chart in 1862 had a single large letter at the top and with each successive row, the letters became more numerous and progressively smaller [11]. It covered a 10-fold range in a 7-step sequence (minimum angle of resolution = 10, 5.0, 3.5, 2.5, 2.0, 1.5 and 1.0 min-arc) [11]. Snellen's original optotypes were serifed letters designed on a framework that was 5 units high and 5 or 6 units wide, and the thickness of the limbs was mostly equal to one unit [12]. Since visual acuity is defined by the angle under which letters are viewed, its measurement can be done at any distance, provided that the scale is adjusted for the distance used. When a letter chart is used as a target for subjective refraction, the viewing distance is important, because the longer the viewing distance, the more accommodation will be relaxed. Snellen's original charts were calibrated for a viewing distance of 20 Parisian feet (in 1862 more than 20 different feet were in use across Europe). As soon as the Treaty of the Meter was signed (1875) he converted to metric distances and made charts for 5 meter (more convenient with the decimal system) and 6 meter (closer to 20 feet). These distances have the advantage that they relax accommodation and that small forward movements of the patient have a negligible influence. The ETDRS protocol reduced the viewing distance to 4 meters to have a more manageable chart size. For refractive measurements, one must be aware that this distance is 1/4 (0.25) D from infinity and adjust the prescription accordingly [13]. After Snellen, many variations in size sequences, chart layout and designs of the optotypes were made. Letters are the obvious first choice for adults. Many different letter sets have been used. Since the establishment of the ETDRS protocol, Sloan letters have become the preferred choice. They are designed on the same 5×5 grid on which Snellen designed his letters. Numbers are the second choice for adults. Even illiterate adults can often recognize numbers. Non-speaking adults can indicate the number seen with simple finger signs. PV numbers are designed on a five and five grid for young children and have been calibrated against Sloan letters. Tumbling E can be used for young children. It is the optotype of choice for many studies in the developing world. Landolt C are often used in research studies, but have found limited application in clinical practice in the US. Tumbling E and Landolt C offer four alternative directions; a prerequisite is that the subject can duplicate this direction, which may be a problem for children with a young developmental age. Children who are too shy to respond verbally, can be asked to match the letter or optotype to one of four flash cards in front of them. For some this is easier than indicating a direction. HOTV charts also offer only four choices. The four letters H, O, T and V have been chosen because they are R/L symmetrical. Numerous picture cards have been designed. A problem is that not all children are equally familiar with all pictures and that many picture sets have uneven difficulty. Most pictures cannot be designed on a 5×5 grid. Patti Pictures are stylized pictures designed by Precision Vision on the basis of the 5×5 Snellen grid and calibrated for equal recognizability against Sloan letters [13]. In summary, there are more than ten types of optotypes for visual acuity evaluation: Sloan Letters, Landolt Rings, Tumbling E, HOTV, LVRC Numbers, 1968 British, PV Numbers, Lea Numbers, Patti Pics, Lea Symbols.

WHAT IS DYNAMIC VISUAL ACUITY?

Visual-vestibular interaction (VVI) is essential for retinal image stability during movement to optimize visual performance [14]. Damage to semicircular canals and otolith organs causes impaired visual acuity during head rotation; impaired balance and postural control; and symptoms of vertigo, falling, nausea and disorientation [15, 16]. Dynamic visual acuity is characterized with the threshold of visual resolution assessed during relative motion, and is a performance measure of VVI. DVA refers to the ability to resolve a target visually when there is relative motion between the target and the observer [17, 18]. Based on current research, the observer must rely on saccades and smooth pursuits to maintain foveal fixation on the image [17]. DVA signal is then transmitted by the magnocellular pathway [19]. Relying on these mechanisms, DVA is a relatively independent visual parameter and is different from static visual acuity [20]. Dynamic visual acuity has been correlated with athletic abilities, aviator spatial orientation, driving frequency in the elderly [14–16], and driving safety [21], contribute to the difficulty in performing of everyday tasks, such as walking [22]. In ophthalmological practice, DVA is not widely used. A clinical Dynamic Visual Acuity Test (DVAT), the Dynamic Illegible E test, can be performed to assess Visual Vestibular Interaction at the bedside. DVA is tested when the patients read the visual acuity chart while they rotate their head from side to side at 1–2 cycles per second. An abnormal response, indicating vestibular dysfunction, is suggested if there is a decrement of more than 2 lines on the visual acuity chart. There are several limitations of the bedside Dynamic Illegible E test [23]. The eye chart can be memorized during the test or on repeated testing when the letters are present even when the head is not moving, allowing the subject to view them and memorize them. The conventional eye charts are scored as the visual acuity line. For example if a subject can see most of the 20/20 line, but missed 2 letters (incorrect), the score would be 20/20 minus 2 letters. This is very difficult to score and analyze statistically. Eye charts used at close distance may invoke disconjugate eye movements. Velocity and frequency are not always well controlled or quantified with either passive (operator generated) or active (subject generated) head movements [23]. DVA tests are generally scored by comparing a baseline visual acuity score obtained with no head movement to a DVA score, with head movement in the vertical and/or horizontal planes [21–25].

STATIC AND DYNAMIC VISUAL ACUITY IN OPHTHALMOLOGICAL PRACTICE

Dynamic vision is related more directly to the visual function state in daily life. A combination of dynamic and static visual evaluations might be an optimal method for detailed visual function assessment [26]. According to theories of dynamic vision, marginal artifacts of the retinal image, which are named retinal smear, have been identified as the cause for decreases in visual acuity with increasing target velocities [27]. With age-related cataract, interaction with light includes occlusive effects and scattering effects, which result in a blurred image on the retina. Retinal smear of a blurred image is much more serious than that of a sharp image [18], and it might explain the significant impact of cataract on DVA. Studies on aging of vision have confirmed that elderly people are less able to extract visual information in the presence of background interference [28].

In the study of Muzdalo NV et al. [29] twenty female and male participants, 65 years of age, took part in the study and the comparison was made with the results provided by 20 20-year old participants. DVA was tested using the Landolt-ring optotype and movement velocity of 72 km/h. T-test demonstrated the presence of a statistically significant difference between dynamic and static acuity among the participants from 62 to 68 years of age ($t=15.852$; $df=39$; $p<0.01$). Within the same group, DVA (mean=0.887; std. deviation=0.297) proved to be significantly worse than SVA (mean=1.40; std. deviation=0.317). By comparing the results measured within the older group of participants with those measured in the younger group, it was shown that there exists a statistically significant difference ($t=0.275$; $df=58$; $p<0.05$) between the older and younger groups in their dynamic binocular acuity with correction. Younger participants had better dynamic binocular acuity with correction (mean = 1.063; std. deviation = 0.259) than the older participants (mean = 0.884; std. deviation = 0.298). The authors state that differences between dynamic and static acuity and its degradation in the older age groups have to be taken into account when issuing driving licenses [29].

Another study done by Aoet al. evaluated twenty-six elderly cataract patients scheduled for binocular cataract surgery and 30 elderly volunteers without cataract [30]. DVA at 15, 30, 60 and 90 degree per second (dps) was assessed, and velocity-dependent visual acuity decrease between consecutive speed levels were calculated. Compared with the control group, the patient group exhibited significantly worse DVA performance at all speed levels ($p<0.001$), and the decreases in velocity-dependent visual acuity were more serious in the patient group at the intervals of 0–15 dps ($p<0.001$), 15–30 dps ($p=0.007$) and 30–60 dps ($p=0.008$). Postoperatively, DVA performance at every speed level in the patient group clearly improved ($p<0.001$) and recovered to levels compatible to the control group. The decrease in visual acuity with increasing speed was less pronounced than during the preoperative phase ($p_{0-15\ dps}=0.001$, $p_{15-30\ dps}<0.001$ and $p_{30-60\ dps}=0.001$) and became similar to that of the control group. The postoperative visual benefit regarding DVA was more pronounced than the improvement in static visual acuity ($p_{15\ dps}=0.001$ and $p<0.001$ at 30 dps, 60 dps and 90 dps). Authors state that the impact of age-related cataract on DVA was more severe than its effects on static visual acuity. After cataract surgery, not only static vision of the patients was restored markedly, but also the dynamic vision.

DVA could be an important adjunct to the current evaluation system of functional vision, thereby meriting additional attention in clinical assessment [30].

Nakatsuka et al. evaluated DVA changes with or without refractive correction [31]. Forty two healthy subjects with normal vision were divided into two age-matched groups. In Group A dynamic visual acuity was measured first with the refractive error fully corrected and then without. In Group B, dynamic visual acuity measurements were taken in the reverse order of that performed by Group A. The measurements were binocularly performed five times using free-head viewing after dynamic visual acuity values were stable. Significant changes in dynamic visual acuity (static visual acuity 20/20 vs 12/20) were observed in both Group A (171.6±36.0 deg./sec. vs 151.8±39.6 deg./sec., Wilcoxon test, $p<0.001$) and Group B (169.8±30.0 deg./sec. vs 151.2±36.0 deg./sec., Wilcoxon test, $p<0.001$). The interaction was significant ($F1.20=8.12$, $p=0.009$). These results indicated that refractive correction affected dynamic visual acuity [31].

Also the effect of pupil size on dynamic visual acuity was evaluated [32]. This study was conducted to assess the effect of pupil size on dynamic visual acuity. Sixty young healthy men (M=28.1 yr., SD=3.9) with normal vision were divided into three age-matched groups by pupil size: dilated (n=20), unchanged (n=20), and constricted (n=20). DVA was measured binocularly with free head viewing before and at 30 min. after each dilated eye drop was instilled. Each of the three groups got a different amount. The sizes of the constricted, unchanged, and dilated pupils were 2.8 mm (SD=0.5), 4.1 mm (SD=0.3), and 7.8 mm (SD=0.5), respectively. The pupil size on DVA interaction was significant ($F(2,114)= 6.07$). DVA in the constricted pupil decreased, but that in the dilated pupil increased (paired t test). DVA in the unchanged pupil did not change significantly (paired t test). Pupil size is possibly one of the factors which may affect DVA measurement [32].

Ethanol effect on DVA was tested as well. Ethanol affects many parts of the nervous system, from the periphery to higher cognitive functions [33]. Due to the established effects of ethanol on vestibular and oculomotor function, the investigation wished to examine its effect on two new tests of the vestibulo-ocular reflex the video head impulse test (vHIT) and dynamic visual acuity. The investigators tested eight healthy subjects with no history of vestibular disease after consumption of standardized drinks with 40% of ethanol. They used a repeated measures design to track vestibular function over multiple rounds of ethanol consumption up to a maximum breath alcohol concentration (BrAC) of 1.38 per mil. All tests were normal at baseline. VOR gain measured by vHIT decreased by 25% at the highest BrAC level tested in each subject. Catch-up saccades were negligible at baseline and increased in number and size with increasing ethanol consumption (from 0.13 to 1.43 cumulative amplitude per trial). DVA scores increased by 86% indicating a deterioration of acuity, while static visual acuity remained unchanged. Ethanol consumption systematically impaired the VOR evoked by high-acceleration head impulses and led to a functional loss of visual acuity during head movement [33].

CONCLUSIONS

The static visual acuity provides only limited information about functional vision, that's why for detail examination we need to evaluate dynamic visual acuity. A number of studies analyzing and measuring the dynamic visual acuity showed that dynamic acuity declines with age or progression of eye diseases. A combination of dynamic and static visual evaluations might be an optimal method for detailed visual function assessment, therefore dynamic visual acuity test should be promoted in ophthalmological practice.

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STATINIO IR DINAMINIO REGĖJIMO AŠTRUMO IŠTYRIMO REIKŠMĖ OFTALMOLOGO PRAKTIKOJE

Santrauka

Statinis regos aštrumas – tai gebėjimas aiškiai matyti nejudantį objektą iš nejudančios pozicijos. Statinis regos aštrumas nurodo regos funkcijos pablogėjimą, kuris gali atsirasti dėl pakitimų tinklainėje, neuroninio apdorojimo sutrikimų, tinklainės neuronų pažeidimų, regos kelio pažeidimo ar kitų regos organo pažeidimų.

Dinaminis regos aštrumas nurodo gebėjimą išskirti objektą, esant judėjimui tarp objekto ir stebėtojo. Pastaruoju metu dinaminis regėjimo aštrumas daugiausia naudojamas elitinių sportininkų regos funkcijai tirti, taip pat tiriant automobilių vairuotojų saugumą. Dinaminis regos aštrumas tampa pirminiu tyrimu studijose, tiriančiose amžiaus poveikį regėjimui. Taip pat buvo nustatyta, kad yra ryškus dinaminio regos aštrumo pablogėjimas didėjant amžiui, ypač pastebimas po keturiasdešimties metų. Klinikinėje medicinoje dinaminis regos aštrumas nėra plačiai naudojamas.

Šiame straipsnyje apžvelgiame statinio ir dinaminio regėjimo aštrumo ištyrimo metodus ir jų vertę oftalmologo praktikoje.

Raktažodžiai: statinis regėjimo aštrumas, dinaminis regėjimo aštrumas, oftalmologija.

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