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Article

Dynamic Visual Acuity

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Abstract

We present a review on the visual ability to discriminate fine details of moving objects (DVA: Dynamic Visual Acuity), showing the most relevant differences, which have been attributed to this visual capacity in comparison to SVA (static visual acuity). It is known that the correlation between SVA and DVA is low. Moreover, when DVA is measured, not only the minimum spatial separation that the visual system can resolve is evaluated, but also the functionality of the oculomotor system. Therefore, assessing DVA also involves measuring the ability of the eye to actively seek information. Nowadays, it is known that DVA is one of the best indicators of success in certain sports specialties (table tennis, baseball, etc...) and that it negatively correlates with accident rates in traffic scenarios. The investigated factors that produce a significant reduction in dynamic spatial resolution are: (a) the speed of the stimulus, affecting both vertical and horizontal trajectories; (b) the stimulus exposure time; (c) ambient illumination; (d) reduction in contrast and (e) subject age. Moreover, it has been verified that this visual capacity is likely to improve with training.

Keywords: Static visual acuity, dynamic visual acuity, visual abilities, movement perception, visual psychophysics.

Acuidade Visual Dinâmica

Resumo

Apresentamos uma revisão do tema referente a habilidade visual para discriminar sutís detalhes diante de objetos em movimento (AVD: Acuidade Visual Dinâmica), mostrando as diferenças mais relevantes, que foram atribuídas a esta capacidade visual em comparação com a AVE (AV estática). Atualmente

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sabemos que a correlação entre AVE e AVD é baixa. Sendo assim, ao medir a AVD não somente avaliamos a mínima separação espacial que o sistema visual pode resolver, também avaliamos a funcionalidade do sistema oculomotor. Desse modo, para avaliar a AVD requer medir a capacidade do olho como buscador ativo de informação. Hoje sabemos que a AVD é um dos melhores indicadores de **êxito** em certas especialidades desportivas (tênis de mesa, baseball, etc.) e que se correlaciona negativamente com sinistralidade nos acidentes de trânsito. Entre os fatores investigados que produzem una redução significativa da resolução espacial dinâmica destacam: (a) a velocidade do estímulo, que afeta tanto as trajetórias verticais como horizontais; (b) o tempo de exposição do estímulo; (c) a iluminação ambiental; (d) a diminuição do contraste e (e) a idade do sujeito. Por outro lado, verificou-se que esta capacidade visual é suscetível a melhorar com treinamento.

Palavras-chaves: Acuidade visual estática, acuidade visual dinámica, habilidades visuais, percepção do movimiento, Psicofísica visual.

Agudeza Visual Dinámica

Resumen

Presentamos una revisión del tema relativo a la habilidad visual para discriminar detalles sutiles sobre objetos en movimiento (AVD: Agudeza Visual Dinámica), mostrando las diferencias más relevantes, que han sido atribuidas a esta capacidad visual en comparación con la AVE (AV estática). Actualmente, es sabido que la correlación entre AVE y AVD es baja. Además, al medir la AVD no solo evaluamos la mínima separación espacial que el sistema visual puede resolver, sino también la funcionalidad del sistema oculomotor. De este modo, valorar la AVD implica medir la capacidad del ojo como buscador activo de información. Hoy sabemos que la AVD es uno de los mejores indicadores de éxito en ciertas especialidades deportivas (tenis de mesa, baseball, etc.) y que correlaciona negativamente con la siniestralidad en accidentes de tráfico. Entre los factores investigados que producen una reducción significativa de la resolución espacial dinámica destacan: (a) la velocidad del estímulo, afectando tanto a trayectorias verticales como horizontales; (b) el tiempo de exposición del estímulo; (c) la iluminación ambiental; (d) la disminución del contraste y e) la edad del sujeto. Por otra parte, se ha verificado que esta capacidad visual es susceptible de mejorar con el entrenamiento.

Palabras claves: Agudeza visual estática, agudeza visual dinámica, habilidades visuales, percepción del movimiento, Psicofísica visual.

Vision provides very useful information to guide the actions and motor behavior of living beings in their environment. Particularly in the case of humans, dynamic vision, which refers to moving stimuli, satisfies a very important function to aid in a variety of activities related to work, as well as in driving, sports or video games, and in scrolling (that is, reading on displays where the object is moving), etc. Given the importance of accurately assessing this visual ability, in order to optimize professional performance and the quality of life of people, in this study we reviewed the scientific literature on dynamic visual acuity (DVA).

Foveal visual acuity is a measure of the ability of the visual system to detect, recognize and resolve spatial details, in a test with high contrast and a good level of luminance (Artigas, Capilla, Felipe, & Pujol, 1995; Bailey & Lovie-Kitchin, 2013). Pioneering research from a neurophysiological approach performed on macaques (Hubel & Wiesel, 1959, 1962) has allowed distinction between the two main types of visual acuity, static (foveal or central) visual acuity, whose basic neural support is the parvocellular system, and dynamic visual acuity, whose basic neural support is the magnocellular system1[1]. Following the work of Enroth-Cugell (1966), a clear distinction between two types of cells was established: the X-type (with linear spatial summation) and the Y-type (with non-linear spatial summation). From the lateral geniculate nucleus, the visual pathways are projected onto the V1 area, so that the magnocellular cells are projected on the 4C substrate, while the cells of the parvocellular pathway are projected onto the 4B (Livingstone & Hubel, 1988). From this point, two main processing pathways are originated: the ventral (*what system*) and the dorsal-parietal (where system). For further details on the neurological basis of SVA and DVA from a neuroscientific approach, see Farah (2000).

The study of the specific functions of each visual neural pathway in primates was performed through the selective damage of one of them. In general, research reflected certain consensus in relating the tasks of pattern recognition, acuity and color perception with the parvocellular pathway, whereas motion perception would be the main function of the magnocellular pathway (Lennie, 1980; Schiller, Logothetis, & Charles, 1990).

Static Visual Acuity

Static visual acuity (SVA hereinafter) is defined as the ability to distinguish the details of static objects whose image is formed on the retina when the evaluated subject is also stationary. In assessing this visual ability, four basic thresholds can be considered: (1) minimum detectable threshold: ability to perceive the smallest object in the visual field; (2) minimum resolution threshold: ability to perceive as separate two objects that are very close together; (3) minimum perceptible alignment threshold: refers to the ability to detect the alignment between two discontinuous segments whose ends are very close together (Vernier Acuity) and (4) minimum recognition threshold: ability to properly identify the shape or orientation of an object (e.g. a letter). This threshold is commonly referred to as visual acuity (Chan & Courtney, 1996).

The method to determine static visual acuity is illustrated in Figure 1.

Visual acuity is calculated using the inverse value of the visual angle, expressed in minutes, that subtends the smallest detail of the test that should be recognized. The normal or standard visual acuity is considered to be the unit (Helmholtz, 1850, cited by Le Grand, 1991), which means that the minimum detail of the test subtends an angle of 1 minute. In more colloquial terms, this concept means being able to read the letter in Figure 2 clearly, assuming that it measures 7.25 mm at a distance of 5 meters.

Several factors can affect SVA. Some depend on the stimulus and others on the subject. Among those that depend on the stimulus, some of the most important ones are contrast and luminance. Thus, if the contrast between shape and background is low, the object must be larger in order to be discerned. In addition, luminance between 0.01 and 200 cd/cm2 tends to yield a progressive increase in visual acuity, but this effect is limited, since too much light can produce glare and interfere with vision (Bennet & Rabbets, 1992).

Among the subject factors that may influence SVA, one of the most determinants is the refractive error, which, in most cases, would require the appropriate optical prescription to achieve normal visual acuity (Eames, 1953). Another very important element is the age of the subject, which is known to lead to anatomical and physiological changes that adversely affect visual perception (Pitts, 1982; Weale, 1978).

Static visual acuity is the visual ability most frequently evaluated and analyzed at a clinical level. The most common optotypes used to measure static visual acuity are the Snellen letters and Landolt's C or ring (see Figure 3). That is, tests that are dated more than 100 years ago (see Artigas et al., 1995) and other more recent ones (Ginsburg, 1984; Pelli, Robson & Wilkins, 1988).

[1] Nevertheless, since detecting fine-grain details is also required in DVA, the moving stimulus has to be foveated through eye fixations and saccades. Therefore, the parvocelllular system is also involved.

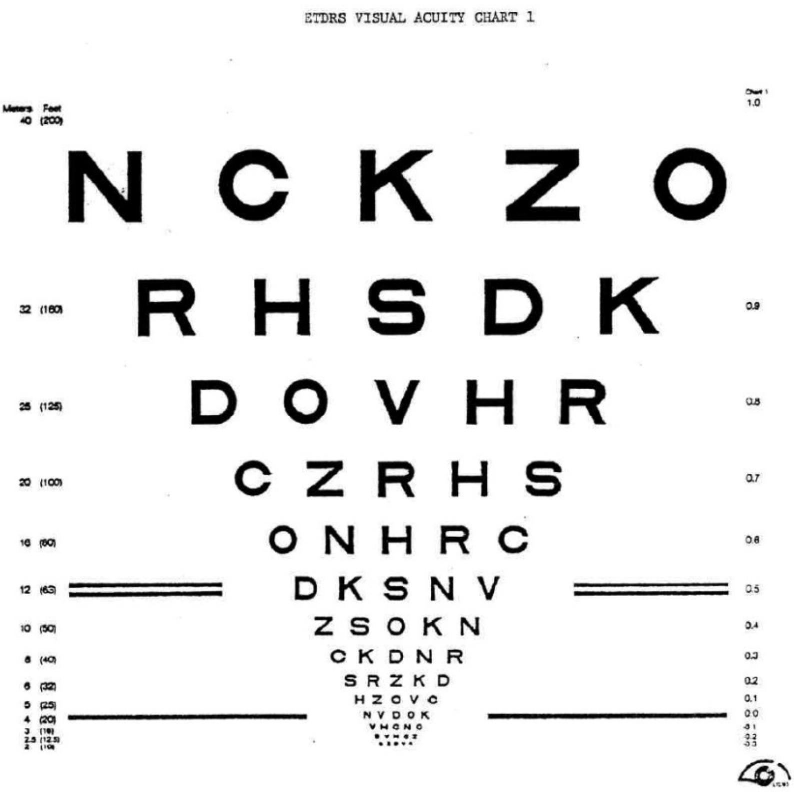


Figure 1. **An optical card (Optotype) similar to a Snellen chart that observers should look at from a certain distance. The method to determine static visual acuity consists of presenting the observer with dots, lines or rings with a certain separation between them, which decreases until the visual acuity limit (psychophysical method of limits GT Fechner) is achieved. The limit of spatial resolution (the smallest size) that the subject can visually resolve is reached when he is unable to identify the letters of a row (or perceive the distance between two points or lines or the opening of a ring). The absolute threshold for spatial resolution or visual acuity (VA) is usually found close to 0.5 arc-minutes of visual angle. To have a reference, for example, a letter of 1 cm in height subtends a visual angle of 1 degree when viewed from a distance of 57 cm. The (Vernier) Acuity for humans is approximately 5-10 arc-seconds of visual angle.**

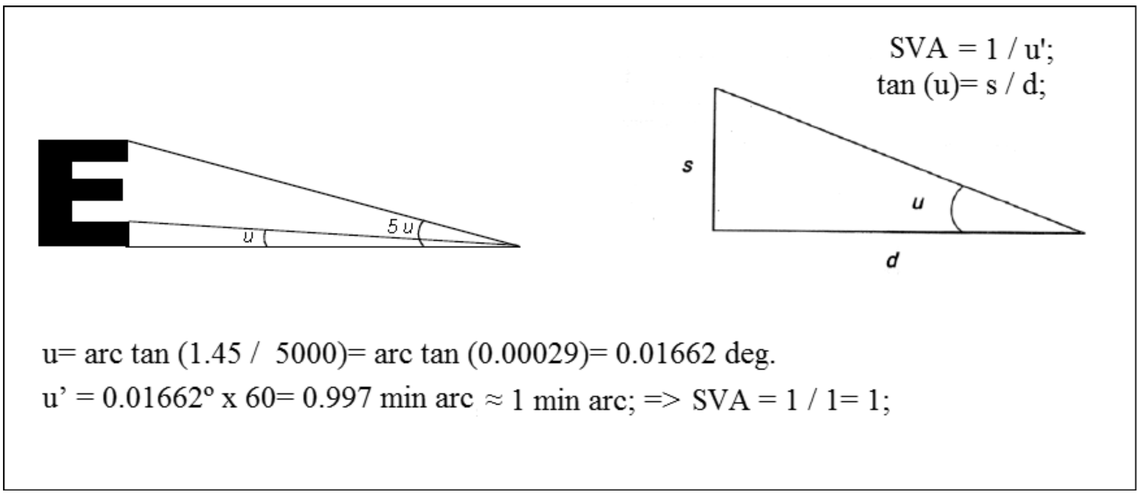
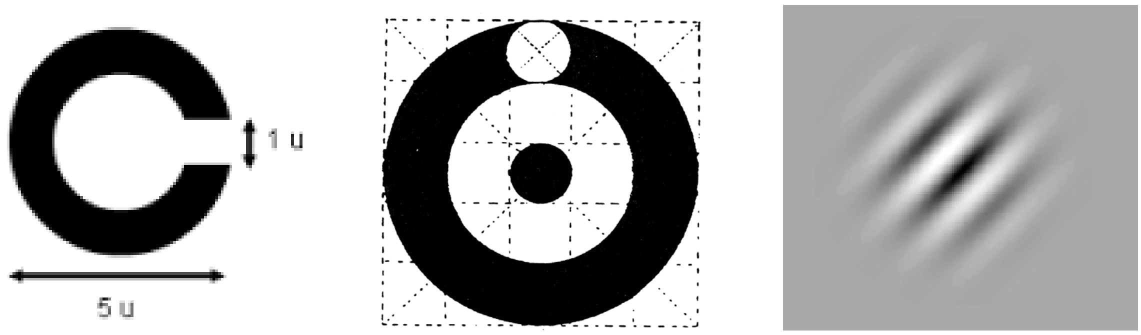


Figure 2. **Calculation of the Static Visual Acuity (SVA) in a Snellen-type optotype. It is assumed that the observer looks at the letter from a 5 m distance (d = 5m) and that, therefore, the height of the letter will be 7.25 mm and the thickness of the horizontal feature will be s = 1.45 mm (s = size).**



Landolt C Palomar ring-disc Gabor patch

Figure 3. Three optotypes used in measuring visual acuity (VA): (1) the classic Landolt's ring, (2) the Palomar universal ring disk, and (3) a Gabor patch. The Landolt's ring is a circular optotype with a discontinuity or gap. To assess AV with this eye chart, the observer is asked to look at each row of the optical card and has to indicate in which orientation is the discontinuity. The Palomar universal ring-disc (Palomar, 1991) has the advantage that it subtends the same angle in all retinal meridians. Note that the peripheral white disc and black central circle correspond in every size to the minimum separable and among all its strokes there is always the same separation. This is the reason why with this optotype visual acuity can be calculated with high precision. The figure shows the ring-disc inscribed in a square divided into five horizontal and five vertical parts where we can see that all its elements subtend the same angle. The right panel of the figure shows an illustration of a Gabor patch which could be used as optotype-stimulus with an orientation of 135 degrees. The luminance of the background is equal to the mean luminance of the Gabor function. This is a grey level representation of the 2-D Gabor function. Of course, the Gabor patches could vary in both spatial frequency and speed or temporal frequency with patch drifting. Participants must indicate the orientation of the stripes.

There are two limitations that show the inadequacy of measuring only SVA to assess the functioning of the visual system (Long & Zavod, 2002). Firstly, many visual stimuli to which we must respond to in real life are often in motion. Secondly, the SVA tests refer to letters or symbols often displayed under conditions of maximum contrast (black on white), even though such high level of contrast is seldom observed in the different situations of daily life.

Dynamic Visual Acuity: Modulating Factors

The term dynamic visual acuity (DVA) was used in 1949 by Ludvigh and Miller to describe the ability to visually resolve subtle spatial details of an object when the object, the observer, or both, are moving (Miller & Ludvigh, 1962). The Dictionary of Visual Sciences defines DVA as the ability to discriminate details of an object when exists relative movement between the object and the observer (Cline, Hofstetter, & Griffin, 1980).

Research has revealed that DVA is modulated by the contrast between the stimulus and the background against which it moves (Aznar-Casanova, Quevedo, & Sinnet, 2005; Brown, 1972; Long & Garvey, 1988; Mayyasi, Beals, Templeton, & Hale, 1971; Zhan, Yager, Lee, & Bichao, 1994). Furthermore, the correlation between DVA and SVA is typically low and increases inversely proportional to the speed of the stimulus. In fact, it is common to find significant individual differences in DVA in subjects with a similar SVA (Long & Penn, 1987; Ludvigh & Miller, 1958). On the other hand, the movement of the stimulus generally hinders the precise discrimination of the details of the visual stimulus. Consequently, a subject's visual acuity is reduced as the speed of movement of the objects increases (Aznar-Casanova et al., 2005; Morrison, 1980; Prestrude, 1987). Different researchers differ significantly with respect to the speed at which DVA starts to be significantly hindered, reflecting differences in obtaining the measure of DVA according to the procedures and experimental conditions used. Thus, Weissman and Freeburne

(1965) established the 120°/sec (practically no correlation between SVA and DVA would be obtained), whereas Brown (1972) suggested the 25-30°/sec (with high correlations between SVA and DVA), and while Prestrude (1987) pointed out that 50°/sec would be the speed limit from which such impairment of visual performance would start. This decrease in visual acuity has been observed for stimuli that move both on a horizontal and a vertical path (Hulbert, Burg, Knoll, & Mathewson, 1958; Miller, 1958). One explanation for this effect can be found in the fact that SVA is mainly related to the power of ocular resolution, while DVA is also closely linked to the functionality of the oculomotor system. Therefore, dynamic visual acuity would decrease with respect to SVA as the eyes cannot properly follow the object when it moves at a high speed. According to Gresty and Leech (1977), the maximum speed at which a moving object can be properly followed by the eye is approximately 30°/sec. At higher speeds, the eye's pursuit movements become mixed with saccades in an attempt to correct the position errors of the retinal image, resulting in a loss of visual acuity. Therefore, the extent to which the limits of the eye's pursuit movements of a person correlate with his DVA should be experimentally verified. In this regard, Sanderson (1981) reported a certain individual susceptibility to speed, suggesting that, while some people might be described as "resistant" to speed, others could be classified as "sensitive" to it, as they would exhibit a rapid deterioration of DVA with increasing speed of the object.

Regarding the exposure time, or the duration of the visualization of the object, it is also commonly accepted that DVA decreases when it is short (Elkin, 1962; Miller 1958). Thus, Fergenson and Suzansky (1973) concluded from their research that the effect of exposure time had an even greater influence on DVA than changes in the object's speed. In this sense, Adrian (2003) proposed a formula to compensate for the decrease in DVA caused by a shorter exposure time by increasing the contrast of the stimulus, or if this contrast was at maximum, to increase the size of the letters. Thus, this researcher concluded that all these factors were strongly interrelated.

Similarly to what happens with SVA, DVA improves by increasing the luminance, yet it is more rapidly affected when it decreases (Miller, 1958). This author noted the benefits of increasing the luminance in parallel with the speed of movement, establishing that while 5-10 cd/ft^2 would be sufficient to discriminate a static object, discriminating the same object while it moved would require up to 125 cd/ft^2.

Aznar-Casanova et al. (2005) measured DVA for two types of movements, hitherto considered equivalent. One is known as *drifting-motion* and other as *shift-motion*. The latter can be described as the horizontal movement of a stimulus, which involves pursuit (or tracking) eye movement, and moving the stimulus from the gaze's fixation point to the periphery. The drift movement of a Gabor patch, for example, prevents pursuit eye movements, as the gaze is fixed to a point of the patch. The data showed that in both types of movement, the visual acuity (VA), expressed in terms of spatial frequency, decreased as the speed of the 'target' increased (see Figure 4). However, the equation's regression slope revealed that this deterioration was twice as much in the case of drift movements, compared to the shift movements. The greatest decline occurred when there were no pursuit eye movements. These data would suggest that these two types of movement correct slippage of the retina in different ways. This retinal slippage was compensated less efficiently in the case of drift motion, having adverse consequences on DVA while the retinal slippage had a greater tolerance in the case of the shift motion.

It seems to be quite accepted that men have better dynamic visual acuity than women (Burg & Hulbert, 1961; Ishigaki & Miyao, 1994). These studies suggest that since there are no sex differences in SVA or in contrast sensitivity, the greater performance of men in DVA could be due to educational and behavioral factors, rather than being an innate cause. In fact, Quevedo, Aznar-Casanova, Merindano, Solé, and Cardona

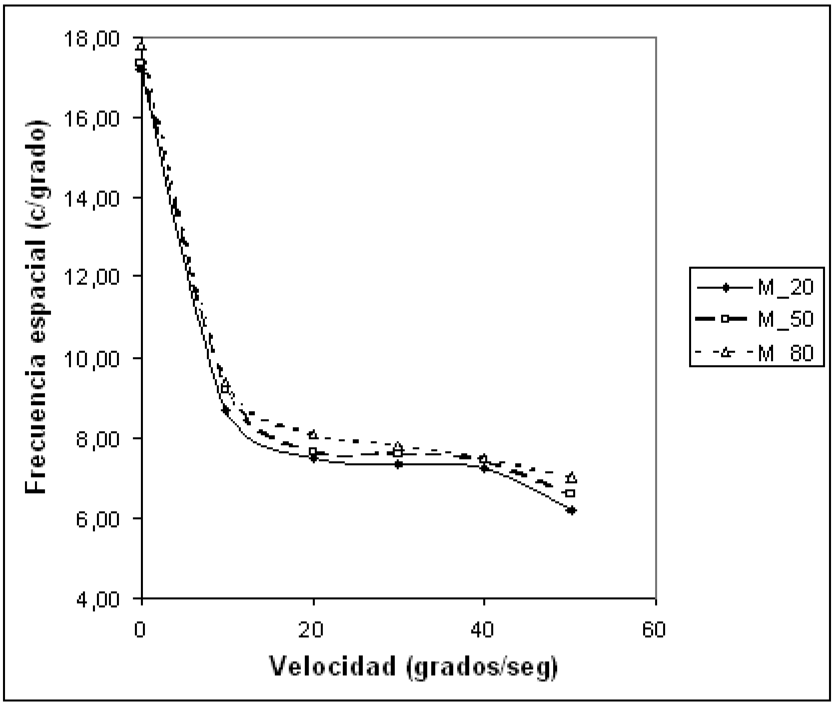


Figure 4. Function that represents the highest spatial frequency that a human subject can discriminate in a certain range of speeds for different contrasts (Taken from Aznar-Casanova et al., 2005).

(2011) found no differences in this respect when young athletes of both genders who performed the same activity were compared.

Furthermore, Cratty, Apitzsch, and Bergel (1973), in a study performed on 475 children of different races and ages between 5 and 12 years, concluded that there were no racial differences regarding DVA, although subjects with light colored eyes yielded higher DVA and ametropic children with minor corrections yielded lower DVA than the emmetropic cohort.

From an evolutionary point of view, it has been found that DVA is one of the abilities that more greatly deteriorates with age. This deterioration is more marked than SVA, and also begins earlier. Ishigaki and Miyao (1994) noted that DVA develops rapidly between 5 and 15 years of age, and that it begins to decline after the age of 20. Burg (1966) showed that, compared with the average results obtained for a population group of 20 years old subjects, DVA was approximately a 60% lower in subjects in their 70's. Accordingly to Long and Crambert (1990), the loss of retinal sensitivity typical of this population is largely responsible for the decline in DVA among the elderly. However, other authors suggest as a more important cause the physiological deterioration of pursuit eye movements and saccades, not only in speed and efficiency, but also in latency (Eby, Trombley, Molnar, & Shope, 1998).

From an applied point of view, the visual perception of movement, with which DVA is closely related, is essential for the adaptation to the dynamic and ever-changing environment surrounding us. Thanks to the dynamic vision ability, it is possible not only to perform daily tasks such as sports or driving, but also to predict the future location of a stimulus that moves. This anticipatory ability is crucial to intercept a moving object (e.g. a ball) and to predict the spatial location of items of interest. Perhaps this is the main reason why numerous scientific studies report a greater DVA for elite athletes compared to sedentary population. This superiority has been found at a general level (Ishigaki & Miyao, 1993), in basketball (Beals, Mayyasi, Templeton, & Johnson, 1971), in volleyball (Melcher & Lund, 1992), in tennis (Cash, 1996; Tidow, Brückner, & de Marées, 1987) and in water polo (Quevedo et al., 2011). Moreover, differences have also been found when comparing athletes'

DVA in a dynamic context (e.g. basketball or tennis) with other modalities with less "visual" requirements such as swimming, with a marked superiority in favor of the first (Tidow, Wühst, & de Marées, 1984).

Quevedo et al. (2011) analyzed the differences in dynamic visual acuity among elite and sub-elite water polo players, and sedentary students. In order to measure binocular dynamic visual acuity, participants were asked to indicate the direction of opening of the Palomar Universal optotype (Palomar, 1991), which is similar to Landolt's C, and which increases in size as it moves across a computer screen (Quevedo, Aznar-Casanova, Merindano, & Solé, 2010). Two different speeds and three possible pathways in two levels of contrast (high and low) were evaluated. Statistically significant differences between elite and sub-elite players in comparison to the sedentary population were found for each combination of speed, contrast and trajectory. Players achieved the best results in dynamic visual acuity. The comparison between the elite and sub-elite groups, however, revealed no differences.

Focusing on the area of road safety and driving, it has also been found that DVA is substantially linked to performance in a quite large amount of daily activities such as reading road signs (Long & Kearns, 1996), driving cars (Burg, 1967, 1968; cited by the National Research Council's [NRC] Committee on Vision, 1985) and flying aircrafts (Kohl, Coffey, Reichow, Thompson, & Willer, 1991). In this sense, Henderson and Burg (1973, cited by the NRC Committee on Vision, 1985) found a high negative correlation between truck and bus accidents and the drivers' DVA. It seems that, in the various studies carried out in which the relationship between different visual abilities and adequate driving was assessed, DVA proved to be the measure that best predicted success in driving (evaluated in terms of traffic accidents).

In addition, it should be noted that another group of research studies (Holliday, 2013; Long & Riggs, 1991; Long & Rourke, 1989) have shown the possibility of improving DVA through training, also suggesting the need to develop appropriate instruments for this purpose.

Finally, in one of the most recent studies (Muiños & Ballesteros, 2015), ways to promote healthy aging and neuro-plasticity were assessed in order to counteract perceptual and cognitive deterioration. The aim of the study was to investigate the benefits of practicing martial arts such as intense and sustained judo and karate, in two groups, one of athletes and another of non-athletes, divided by age into another two groups (young and old), by comparing their DVA. These authors used the DVA test designed by Quevedo Junyent in 2007 (Quevedo, Aznar-Casanova, Merindano, Cardona, & Solé, 2012). The results showed that (1) athletes obtained better DVA than non-athletes; (2) the group of older adults showed a greater oblique effect than the youth group, independently of whether they practiced a martial art or not; and (3) age modulated the effect of sport, but only under the condition of high speed of the dynamic stimuli. Thus, young karate athletes' DVA was higher than non-athletes, while most judo and karate older athletes yielded greater DVA than non-athletes. The authors concluded that the systematic practice of a martial art such as judo or karate influences the neuro-plasticity of an aging human brain, diminishing the neuro-cognitive decline assessed through DVA.

Instruments Used to Evaluate Dynamic Visual Acuity

Unfortunately, despite the importance of DVA, specific instruments with proven reliability and validity that enable further research of such ability are scarce or inadequate (Banks, Moore, Liu, & Wu, 2004; Zimmerman, Lust, & Bullimore, 2011). It should be noted that the tests traditionally used to evaluate dynamic visual acuity usually involve rotating disks (similar to old record players or turntables) which spin an optotype of black letters on a white background. Among the criticisms noted by various authors (e.g., Coffey & Reichow, 1990), their lack of specificity (as it is rare to find circular trajectories, which cause excessive ocular cyclotorsion and conditions of maximum contrast, in real life) and the fact there are no studies to support their reliability and validity should be highlighted. This shortage of instruments to measure DVA translates into a certain disorder in the obtained results and therefore, a clear difficulty in establishing comparisons between them.

One of the devices designed to evaluate DVA and obtain normalized data is called Kirshner's Rotator (1967). When using this instrument, the evaluated subject must identify the orientation of a Landolt's C (corresponding to a demand for visual acuity of 20/40) which describes circles (movement trajectory) and is projected on a screen three meters away from the subject being evaluated. The opening of Landolt's C can be directed up, down, right or left. The diameter of the circle described by the stimulus is 55cm and rotates in a clockwise direction. The stimulus begins to move at a speed of 100 rpm and gradually decreases until the subject can correctly identify the orientation of the Landolt's ring three consecutive times (limits method). This test should be performed in low light conditions to facilitate the subject's ability to discriminate the projected stimulus.

Other instruments commonly used in a clinical setting, in the context of sport optometry, are the Pegboard Rotator machine (JW Engineering, 24 Phyllis Dr, Pamona, NY 10970) and Bernell's Rotator Disc (422 E Monroe St, South Bend, IN 46601), which can be seen in Figure 5. Both are inspired on the mechanics of the classic "turntables" and use optotypes with letters of different sizes (corresponding to visual acuity of 20/30 and 20/60 for Pegboard, and 20/20, 20/30 and 20/40 for Bernell) which can rotate clockwise or anticlockwise. It should be noted that the dynamic visual acuity values are recorded as a combination of visual acuity and speed in rpm (e.g. 20/40 at 45 rpm).

Figure 5. Bernell's Rotator is frequently used for the clinical evaluation of DVA, especially in a Sport Optometry context.

Several authors such as Coffey and Reychow (1990) suggest the need for further research in this area in order to develop measurement instruments more specific to the visual needs of drivers and athletes, which may not only allow for objective, valid and reliable assessment of dynamic visual acuity with a stimulus that describes circular paths, but also with lateral, vertical and oblique paths across the visual field.

Quevedo et al. (2012) proposed the DinVA 3.0 test, implemented through a computer program, which is frequently used in the evaluation of athletes' DVA (see Figure 6). More recently, Quevedo, Aznar-Casanova, Solè, and García-Giménez (2014) have updated this computerized test to the C# programming language. It should be highlighted that the computer equipment required to present and record DVA should include a powerful graphics system: (a) screen with a refresh screen rate (frame rate) of 120 Hz or higher, and (b) an accelerated graphics card (for example, Nvidia Geoforce or AMD Radeon).

The new software (DynVA test) allows the use of various stimuli and the selection of their color and intensity, as well as colors or photographs (related to the usual environment of each task) that make up the background. Furthermore, as the stimulus crosses the display, it can describe lateral, vertical, oblique, and linear trajectories. In order to establish the maximum possible resemblance to a real-life environment, the test can be performed at a distance greater than the 50 cm that are most common when working with a computer (see Figure 7).

Final Comments

DVA evaluates the spatial resolution of the visual system when presented with moving stimuli. This visual ability is particularly useful when the speed of the stimuli exceeds 30-60°/sec. Probably, DVA is one of the visual abilities with the greatest ecological validity and undoubtedly constitutes a good predictor of performance in the execution of numerous tasks and activities of daily life, including sports and driving. However, this predictive value has scarcely been exploited, either within the aforementioned areas, or within work performance. Therefore, there is a clear need for an instrument to measure DVA, which involves the contrast factor in the luminance of the background and shape. In fact, more than thirty years ago, the NRC Committee on Vision (1985) of the United States of America stated in their book "*Emergent Techiniques for Assessment of Visual Performance*" that the combination of DVA measures AVD, along with those for CSF, would certainly provide more valid and powerful evaluations of the functionality of the visual system than SVA, and recommending the inclusion of the evaluation of the first batteries of visual tests for drivers, airline pilots and athletes. In the literature reviews conducted since then, various authors have emphasized the paucity of published work, probably due to the lack of an easy to use instrument to measure this visual ability. Hence, this leads to a limited knowledge of DVA and its applications (Banks et al., 2004; Hoffman, Rouse, & Ryan, 1981). Most of these studies on DVA have primarily focused on determining the moving stimulus' factors influencing DVA, such as size, contrast, angular speed of movement and exposure time. Thus, it has been found that a subject's DVA is reduced by increasing the speed of the stimulus' movement (Ludvigh, 1949; Morrison, 1980; Prestrude, 1987). However, different researchers, reflecting the differences in methods and experimental conditions used, substantially differ with respect to the speed at which dynamic visual acuity begins to be markedly deteriorated.

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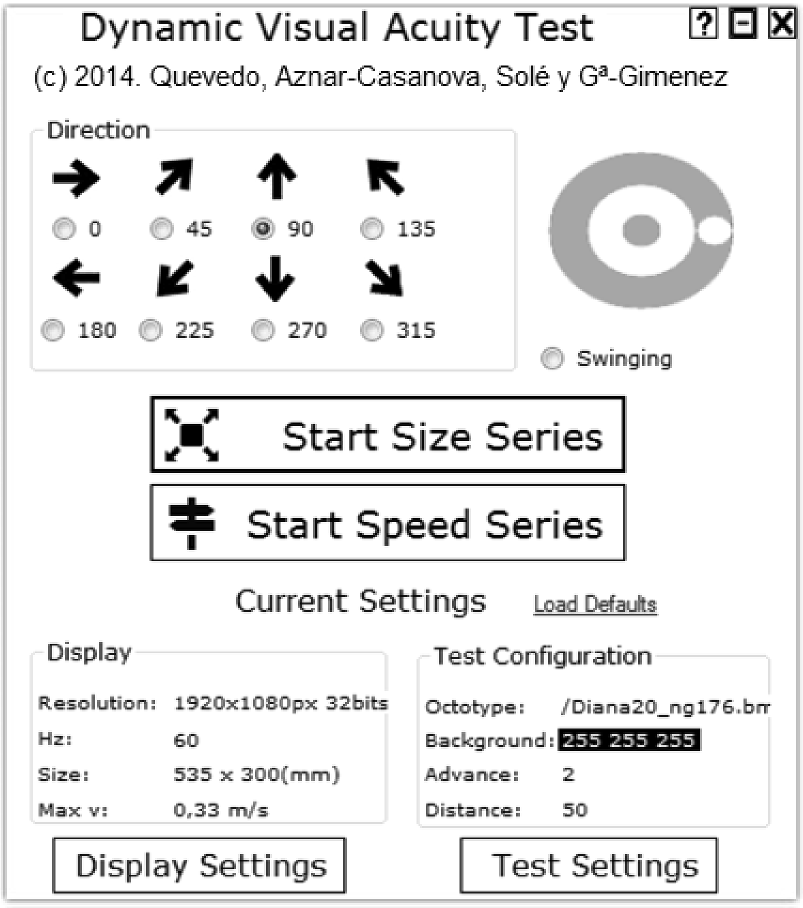

Figure 6. The DynVA is a computer software designed to assess DVA. The researcher can select the optotype to be presented in the two forms of the test: (a) Size Series; (b) Speed Series. In the Size series, the optotype size remains constant, while its speed decreases as it moves across the screen. Conversely, in the Speed series, the optotype speed remains constant while its size increases progressively as it moves across the screen. In both series, the trial ends when the subject presses the arrow key that matches the position of the band gap of the test card.

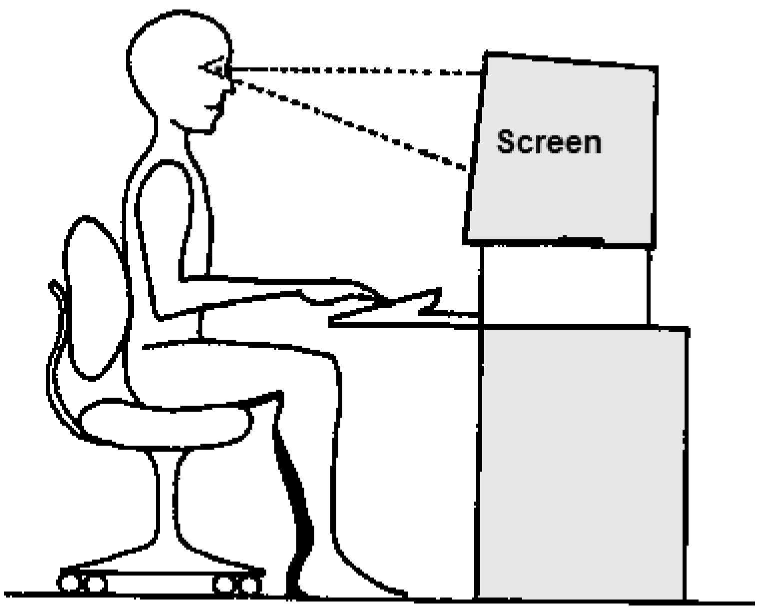

Figure 7. How does compute the speed of the stimulus on the retina? To compute DVA, the software first calculates the speed of the stimulus on the screen according to the following formula: Speed (in m/s) = Frame rate (in Hz; frames/s) * Dot_pixel (in m) * Step (in pixels). Then, to calculate at what speed the stimulus moves across the retina (to obtain the speed in degrees of visual angle), two factors must be taken into account: (1) the speed of the target on the screen, in meters per second, and (2) the viewing distance (usually in m): Speed on the retina = arc tan (on screen_speed / Viewing distance). For example, given a target speed on the screen of 0.420 m/s and a viewing distance of 2 m, the speed would be 11.86°/s of visual angle. The DVA is then expressed as the smallest detail that the observer is able to perceive at that speed.

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Appendices

Highlights

1. Dynamic Visual Acuity (DVA) measures discrimination in moving objects.
2. The correlation between SVA and DVA is about 0.40, starting from speeds of 30°/sec.
3. DVA measures the eye's spatial resolution and the function of the oculomotor system.
4. DVA assumes that the visual system actively seeks information.
5. DVA is one of the best predictors of success in sports (table tennis, baseball).
6. A low DVA correlates with high accident rates in traffic incidents.
7. DVA is influenced by: (a) the speed of the stimulus; (b) exposure time; (c) ambient illumination; (d) luminance contrast of the stimulus; (e) subject age.

Glossary

Dynamic Visual Acuity (DVA)**:** describes the ability to visually resolve subtle spatial details of an object when itself, the observer, or both, are moving.

Static Visual Acuity (SVA)**:** is the ability to distinguish spatial details in static objects when the subject is not moving.

Luminance contrast**:** the relationship between the luminance of an object (stimulus) and the luminance of its immediate environment (or background against which the stimulus is shown).

***Degrees of visual angle per second* (°/sec.):** unit to express the speed with which a mobile stimulus crosses the retina.

Power of Spatial Resolution**:** ability to perceive as separate two objects that are very close in space.

Pursuit movements**:** also called tracking movements of a moving stimulus. They allow to foveate the retinal projection of the stimulus.

Saccadic movements**:** short and rapid eye movements that allow the observer to detect an object at a particular location in the visual field and place it on the fovea, for a better discrimination.

Oculomotor system**:** it refers to the extra-ocular muscles that control eye movements. In the case of DVA, these are pursuit or tracking movements and saccadic movements.