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Visual Acuity and its Dependency on Observation Time and Contrast

Werner Adrian, University of Waterloo, Canada

Abstract

Field studies on the duration of fixation during driving reveal that in daytime the fixation rests on average about 0.2 seconds on a point in the field of view. Thus, the time available to read traffic signs is limited.

In order to obtain quantitative data, the Visual Acuity and its dependency on the observation time had been investigated in two independent studies. Landolt-Rings in negative contrast were presented on a computer-screen of 10 – 40 cd/m² Luminance as a background. The display of the rings could be varied between 2 and 0.02 seconds and shown in different contrasts.

It became evident that the Visual Acuity depends on the log of the light dose reduced by the transmission in the eye media, so that absorbed photons seem to determine Visual resolution. For young observer it was found:

$$VA = \log \Delta L \cdot t \wedge 0.57 + 1.705$$

with $\Delta L =$ Luminance difference between
target and background in cd/m2
$t =$ observation time in seconds

VA decreases with shorter observation time and lower contrast that can be described by an algorithm for calculation.

Introduction

Visual resolution of details which can be expressed as Visual Acuity constitutes a visual function that determines visual performance of reading tasks. Visual Acuity is well known as a function of background luminance and contrast of the optotype, but there is little known about the dependency on observation time; the time that remains to foveally view the optotype or letter.

In traffic the observation time of a sign is often limited to a fraction of a second and we need to know how to compensate for the effects of short durations. While in field studies the average fixation time of a point in the field of view was found to be 0.2 sec. in daytime, the time to recognize a sign message can be considerably shorter.

Figure 1 Traffic sign on the approach to Toronto International Airport. The Visual task is to find the Terminal number on the right of the sign for the airline used. This task has to be carried out while driving by on a highway at a speed of around 100km/h.

An example of a reading task in traffic is given in figure 1, which depicts the approach to the Toronto International Airport, where the number of the terminal for the different airlines has to be found. Fortunately the traffic engineers decided to display the airlines in alphabetical order and later on introduced a colour code to identify the different terminals, that impairs the ability to read the number. When passing these signs with a speed of for example 72 km/h, which relates to 20 m per second, it is difficult to catch the information needed to find the right terminal.

For that reason experiments in the laboratory had been conducted to reveal the basic dependency of Visual Acuity on the time of observation.

Method

As a criterium for measuring the Visual Acuity the “Landolt Ring” method was recommended by international convention.

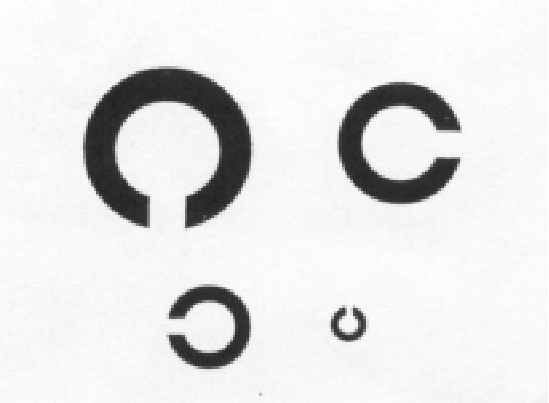

Figure 2 Example of Landolt Rings used as a criterium to measure Visual Acuity. The gap size represents the critical detail that has to be perceived. VA=1/δ with δ the angular size of the detail in minutes of arc.

Figure 2 shows such Rings in high contrast. The angular size of the gap in the ring that equals the width is used as the detail to be resolved. For example, if the detail subtending 2 minarc can be correctly recognized in 80 % of the presentations, this would relate to a VA of 0.5, as by definition, VA is expressed as the inverse of the visual angle of the resolved detail in minutes of arc. The Landolt Rings were displayed on a monitor of 32cd/m^2 screen luminance, one at a time at constant negative contrast of the ring. The observer pressed one of 4 buttons pertaining to the direction where the gap of the ring was showing. After the threshold acuity was found, the process was repeated with different presentation times and contrast of C=0.74, 0.46 and 0.17. The experiments were performed in two different investigations with 6 young, fully corrected observers of 22-26 years.

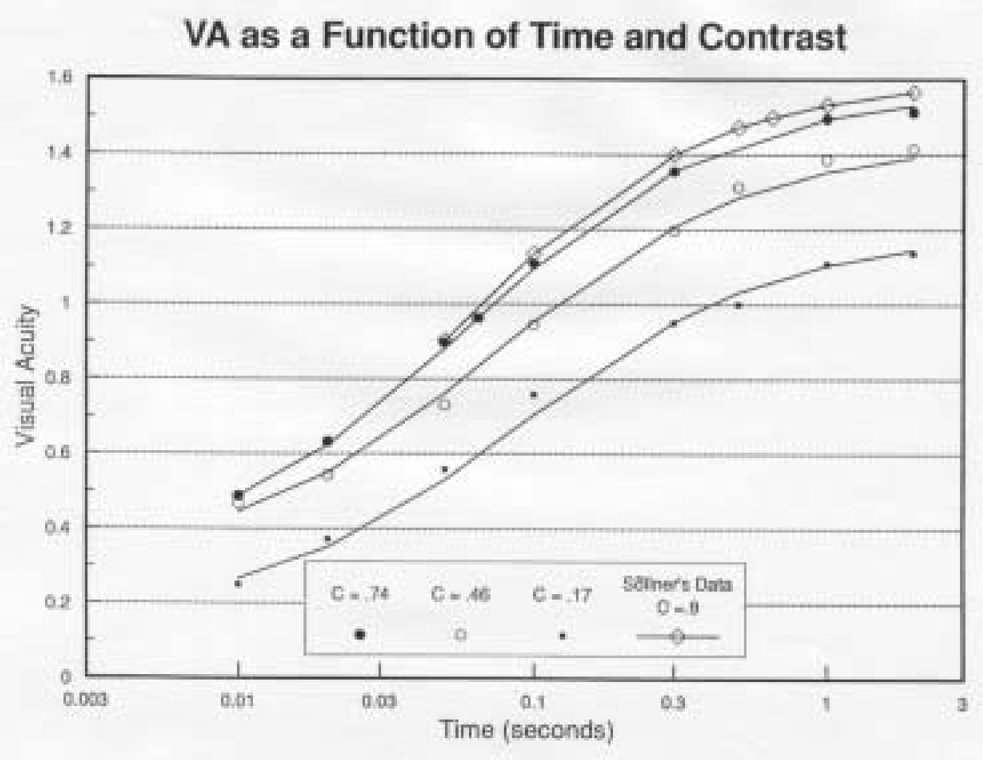

Figure 3 Resulting form perception expressed as Visual Acuity from two independent investigations as a function of display time and contrast of the optotypes appearing dark on a background luminance of ~ 32 cd/m^2

Both investigations produced the same results which are plotted in Figure 3 as Visual Acuity versus the exposure time for three different contrasts of the rings. Söllner in 1963 conducted experiments in which a Landolt Ring was moved horizontally and shown in an opening of constant width. By variation of the speed, exposure times could be simulated. In his case the ring was moved, in ours the Landolt C was constantly displayed in the center of the screen. His findings of for a Ring contrast of 0.9 were entered into the diagram and show the same tendency.

The data for 0.01 seconds appears to have a slightly upward tendency, which is presumably caused by the time needed by the computer to compose the Landolt Rings. Perhaps these points should be moved to a slightly increased exposure time as there is no physiological reason why VA should turn upwards, leaving the trend for exposure times shorter than 0.02 seconds. The curves are calculated with a formula that was found as best fit through the data. Figure 3 reveals that at exposure times of 2 seconds the well known fact that VA for a given background luminance is strongly dependent on the contrast of the Landolt C. With shorter observation time VA decreases rapidly. At 2 seconds exposure time the observers obtained on average VA=1.5 with a ring contrast of 0.74. If the exposure time is reduced to 0.03 seconds, they achieved only 50% of that value. For the contrast of 0.17 the same reduction of exposure time would decrease VA to 38%

Analysis of the data

It is of interest to investigate what exposure times and contrasts lead to the same Visual Acuity. This was done for VA values of 1.1, 1, 0.9, 0.8, and 0.6. the horizontal lines as in Figure 3 intersect with the family of curves for the different contrasts and give us the exposure times that allow for the same acuity. If we do so, the data as in table 1 follows:

VA	C=.9	C=.74	C=.46	C=.17
1.1	0.086	0.100	.188	1.00
1	0.065	.0716	.12	.39
0.9	0.0460	.0488	.0805	.2230
0.8	-	.0367	.0577	.1492
0.6	-	.0147	.0242	.0648

Table 1: Exposure Times and Contrast leading to the same Visual Acuity

Pairs of the exposure times t and the contrast of the optotype C that leads to the same value of VA forms an expression t x C that is equivalent to a light dose ($\Delta L/L$) x t, with L= background luminance constant ~ΔL x t. These values are contained in Table 2.

t x C

VA	C=.9	C=.74	C=.46	C=.17	Average t x C
1.1	.0774	.074	.086	0.100	.0844
1	.0583	.053	.055	.066	.0581
.9	.0460	.036	.037	.038	.0392
.8	-	.027	.027	.025	.0263
.6	-	.0108	.0111	.0110	.0110

Table 2: Values of Exposure Time "t" multiplied with the Contrast "C" of the Optotype for constant Visual Resolution given as Visual Acuity.