Generating the Snellen chart by computer

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Abstract

The Snellen Chart is the eye chart that is commonly used to measure visual acuity. The chart has combinations of nine different letters in eleven different lines, each smaller than the one above. Repeated measures of visual acuity may result in chart memorization and false information. Thus, a computer program was written to produce randomized multiple versions of Snellen eye charts. The chart may be changed at some distance from the computer in order to hear subject letter identifications during exercise testing. Different sized letters can also be produced so that the distance from the subject to the chart can vary. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

The most common method to test visual acuity is to use the standard Snellen chart [1–3]. This chart is organized with a large 'E' at the top, and ten additional horizontal lines of letters of decreasing size appearing from top to bottom (Table 1). Each line is given a visual acuity score that relates the ability of an individual standing 6 m (20 ft) from the chart to read the letters on that particular line to the same ability of a 'normal' individual to read the same letters while standing

Table 1
Snellen eye chart organization

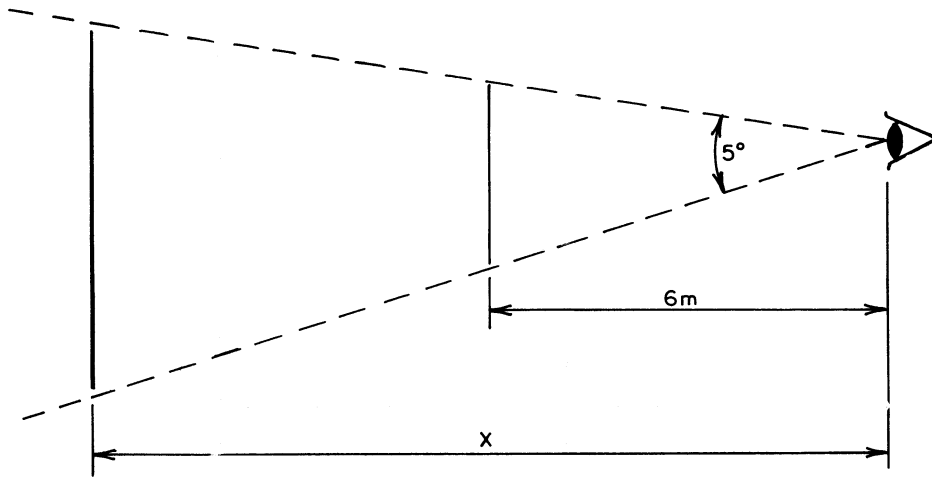| Line number	Acuity score
1	20/200
2	20/100
3	20/70
4	20/50
5	20/40
6	20/30
7	20/25
8	20/20
9	20/15
10	20/13
11	20/10

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Fig. 1. Visual acuity measurements with the Snellen chart are based upon the ability of a particular individual to see at 6 m what a normal individual can see at a different distance, x. Both letters subtend a visual arc of 5°.

at a different distance from the chart (Fig. 1). Thus, a visual acuity score of 20/10 indicates vision better than normal, a score of 20/40 indicates vision worse than normal, and a score of 20/20 indicates vision equal to normal.

We had need to test work performances of individuals wearing respiratory protective masks with lenses clouded to different degrees [4–6]. As part of the protocols for these experiments, subjects were repeatedly tested for visual acuity while exercising on a treadmill. There were three difficulties that we needed to overcome: (1) there was often not enough distance in the laboratory for the subject to stand 6 m from the Snellen chart, (2) repeated use of the same Snellen chart could lead to memorization of the letters, and (3) the attending investigator needed to stand next to the subject to adequately hear subject reading of the letters because of the poor sound transmission through the respirator and the loud background noise generated by a treadmill. Thus, a computerized alternative was sought that maintained the organization of the Snellen chart, but that: (1) could be used at different distances, (2) randomized the order of letters, and (3) could be changed at a distance remote from the computer. The following is a description of the result of these efforts.

2. Snellen chart basis

The Snellen chart uses letters of different sizes for literate persons. Symbols similar to a letter E with different orientations are used for non-literate and young children.

There are nine different letters used on the standard Snellen chart: C, D, E, F, L, O, P, T, and Z. The reason that these letters were chosen is unknown to us, but we assume that these letters were found to be adequate to test visual acuity. Each letter was designed to subtend a visual arc of 5° wide and 5° high. No element in any letter is less than 1° of visual arc (Fig. 2).

Forming these letters was the heart of the computer program. Once the means to form them was written, then the letters could be scaled in size to form different lines or to allow for different distances. The program was written in C^{2+} (Borland, Scotts Valley, CA) and used the graphics driver in the language software in order to form arcs. Custom software might be able to access individual pixels on the monitor, but we had not done this. Thus, there was a limitation on the size of the letters that could be drawn, especially the letters with arcs.

3. Hardware used

The Snellen chart is generated on a computer with a 386 processor. The generating computer is not critical. The computer hardware must support VGA graphics resolution.

More important is the computer monitor. The monitor should be of high resolution with both horizontal and vertical size adjustment and capable of high contrast between white and black. The monitor chosen was an NEC Technologies (Boxborough, MA) MultiSync 3FGe Monitor with 640×480 VGA resolution.
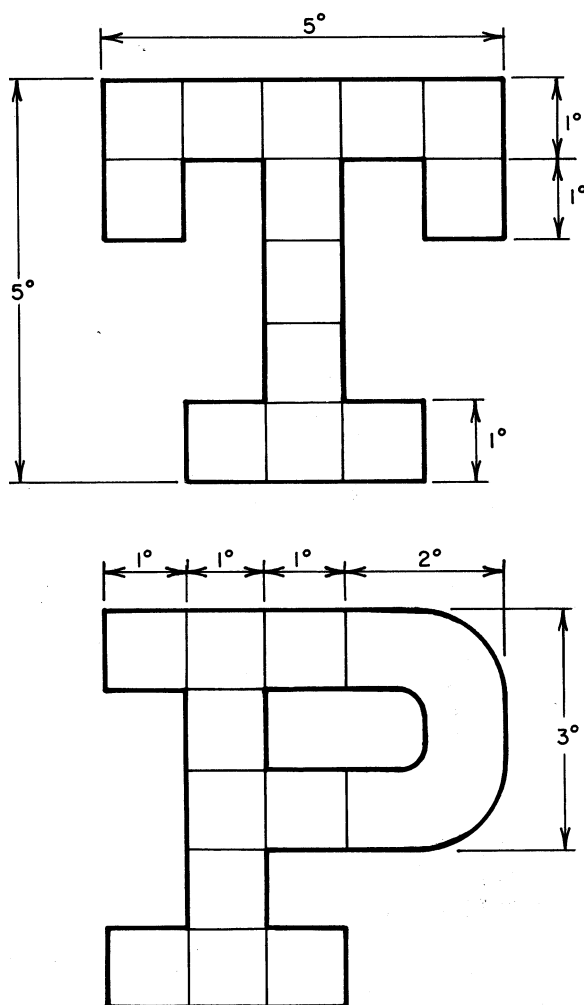

Fig. 2. Two letters from the Snellen chart, showing how they are composed of elements of 1° of visual arc or greater.

An Advanced Gravis (Burnaby, BC, Canada) game pad is used for remote control of the program. Pushing the red button advances the line displayed (smaller letters), pushing the green button displays larger letters, pushing the yellow button displays another random combination of the same sized letters, and pushing the blue button returns to the main menu.

4. Program use

Two compiled executable programs are required: SNELLEN.EXE is the program that forms the Snellen chart and EGAVGA.BGI is the device driver required. The program first displays a square that is supposed to be sized 7.24 cm (2.850 inches) in both horizontal and vertical directions (Fig. 3). The user must physically measure the size of the square and enter the result of this measurement. If the square measures differently than the nominal size given above, then the program computes different distances that the subject must stand from the monitor.

A menu displays three choices: (1) the monitor may be placed 2.5 m from the subject (this choice cannot correctly support Snellen lines for visual acuities of 20/25, 20/15, and 20/13), (2) the monitor may be placed 5.0 m from the subject (Snellen line for 20/13 is not supported), and (3) the monitor is placed 7.5 m from the subject (all lines are supported). Choosing one of these will result in Snellen line 1 (20/400 visual acuity) appearing on the screen. These distances would be different if the square originally displayed were measured and found to be different from the nominal size.

Pushing the 'up' arrow key on the keyboard or the green game button causes the program to display the next line with larger letters. If the maximum sized letter (line 1) is already displayed, then a beep from the computer alerts the operator that a mistake has been made and no display change is forthcoming. Pushing the 'down' arrow key or the red button causes the display of the next line with smaller letters, unless the smallest line has been displayed. In that case a beep is heard by the operator and no change is made in the display. Pushing either 'side' arrow or the
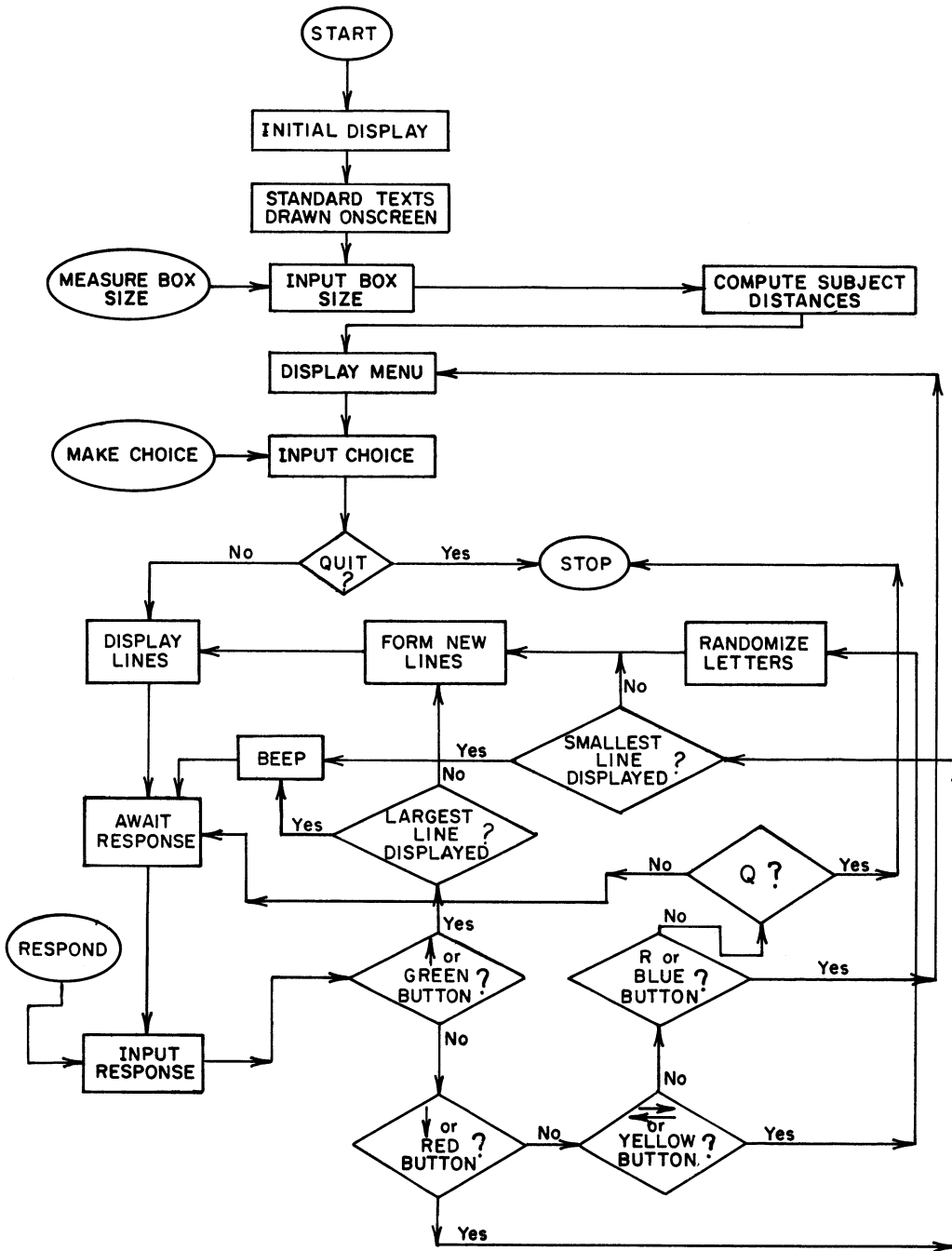
Fig. 3. Program Use Flow Chart.

yellow button maintains the size of the letters but randomizes their order. Pushing the 'R' key or the blue button returns the display to the main menu.

Finally, pushing the 'Q' button followed by 'enter' stops the program; this cannot be accomplished with the game pad.

Table 2
Calibration of computer snellen to standard Snellen chart

Lens	Visual acuity (mean ± S.D.)	Regression equation	Regression coefficient (R^2)	Range
1	3.72 ± 1.05	Sn = 0.911 Comp + 1.061	0.800	4–8
2	5.59 ± 1.06	Sn = 0.801 Comp + 2.009	0.647	4–10
3	6.04 ± 1.04	Sn = 0.822 Comp + 1.717	0.659	3–7
4	6.74 ± 1.02	Sn = 0.791 Comp + 1.458	0.559	2–6
5	7.46 ± 1.02	Sn = 0.87l Comp + 1.147	0.652	2–5
6	7.99 ± 0.995	Sn = 0.912 Comp + 1.390	0.644	3–8
7*	9.00 ± 1.05	Sn = 1.063 Comp + 0.287	0.753	5–11
0**	9.18 ± 1.05	Sn = 1.211 Comp − 1.233	0.691	6–11

* Unaltered mask lens.
** Control; no mask.
Sn standard Snellen chart line.
Comp computer Snellen line.

Comparison between the computer-generated Snellen chart and ordinary charts printed in black on white cardboard shows that the computer-generated chart is not as bright. The brilliant white color produced by the monitor is in reality a very light blue. Lighting conditions in the room can have a large effect on the perception of the displayed letters. The amount of ambient light, the quality (tint) of the light and the presence of glare are all important for generating calibration curves relating the computer Snellen to cardboard Snellen charts. Ambient lighting is important to correct use of the Snellen chart on cardboard, but is often overlooked.

The computer Snellen was tested in a laboratory lighted by overhead fluorescent fixtures to a level of 550 Lux where the subjects stood and 350 Lux where the monitor was located. A piece of cardboard was placed over the top of the monitor to reduce glare from overhead lights.

Twenty-five subjects were used to calibrate the computer Snellen chart. Subjects stood 6.1 m (20 feet) from the Snellen chart and 4.9 m (16 feet) from the computer monitor. They wore standard US Army M17 full facepiece respirator masks to which were attached lenses that had been clouded to different degrees. A control condition without masks was also tested.

Subjects were recruited from the University of Maryland and were between the ages of 18 to 30. They could not wear glasses, since these would interfere with respirator wear, but contact lenses were acceptable. To be considered for inclusion in this study, subjects were to demonstrate at least a 20/30 visual acuity as measured by the standard Snellen eye chart. Subjects were allowed up to one incorrect letter identification on a line with that line still representing visual acuity. Four custom-made Snellen charts, differing from the original order of letter appearance only, were used at various times to circumvent the problem of letter memorization.

In Table 2 are seen the results for each of the eight conditions tested. Lens visual acuities are given as Snellen line values obtained from subjects' responses to reading standard Snellen charts. In all cases there was a standard deviation of one Snellen line. Much of this can be attributed to the quantization error due to discrete Snellen line values and to the allowance of up to one incorrect letter per line.

Data relating standard Snellen chart line score and computer Snellen line score plotted linearly with scatter. The range of lines able to be seen with each lens varied, with larger letters needed for lenses with lower visual acuities. Regression equations relating computer Snellen to standard Snellen line values were obtained for each lens condition. Regression co-efficients were generally of the order of 0.6.

Although the Snellen chart line 8 (20/20) is supposed to represent normal sight, we have

found our subjects to exhibit consistently superior vision. The average visual acuity for our subjects lies somewhere between line 9 (20/15) and 10 (20/13).

5. Conclusions

We have used the program for generating the Snellen chart by computer and found it to be versatile and useful, especially for exercising subjects. The random letter feature and remote feature are especially helpful. A copy of the program may be obtained by sending a formatted 31/2 inch disk to: Arthur T. Johnson, Biological Resources Engineering, University of Maryland, College Park, MD 20742-5711, USA.

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