Fully Automatic Self-administrative Vision Screener

Ying-Yin Rudy Huang †
Department of Industrial Engineering and Management
National Taipei University of Technology (Taipei Tech), Taipei, Taiwan
Tel: (+886) 2-2771-2171 ext. 2336, Email: yingyinhuang@ntut.edu.tw

Marino Menozzi
Department of Health Sciences and Technology
ETH Zurich, Zurich, Switzerland
Tel: (+41) 44 632 39 81, Email: mmenozzi@ethz.ch

Abstract. We present an innovative, fully automatic and computerized vision screening system. The present vision screener enables a self-administrative vision examination environment with ergonomic human-machine-interaction designs. Eight general vision tests are included in the self--vision-screening procedure (far vision, near vision, color vision, contrast vision, stereo vision, and visual field test.) Specific vision test charts and test procedures were designed and defined after following usability engineering tests. The newly developed vision test charts installed in the present screening system demonstrate high efficiency as well as sufficient effectiveness in examining the general visual functions in comparison to the test results applying other standard vision screening procedures. In an average of 10 minutes, the user may accomplish all 8 vision tests by his/her own and receive the test result sheet in real time including some basic evaluation recommendation. A self-made answering box consisting of a hand-held joystick and one button with palm/wrist rest design has been developed after intensive evaluation of the user operating preference and performance in such a radial pointing manipulation environment. The input interface design is intuitive to the user while performing the vision test. The present screening system provides a user-friendly and easy access to self eye health control.

Keywords: vision screening, usability, ergonomic designs, healthcare, pointing manipulation

1. INTRODUCTION

General vision screenings conducted at schools or in organizations usually involve a large-scale screening size resulting in long examination time and requiring much healthcare resources of the expertise and professional instrument. It is important to conduct such screening tests in a regular base, e.g. yearly screenings at school, to check the status of eye health of young students and employees in the occupational health sector. A comprehensive eye check carried out by an eye doctor or optometrist consumes too much resources and therefore is not suitable for a large-scale screening condition. A proper setup of general vision screenings can be carried out in a relatively easy way and may be aimed as a check-up procedure for filtering out or identifying some potential eye problems in an early stage while minimizing and saving the healthcare resources and cost. Introducing a pre-screening phase may save up to 80 percent of the total examination time depending on the investigated visual functions and on the pre-examination duration (Krueger, 1999.) A follow-up eye examination should be carried out by an eye doctor with more intensive check procedures requiring more sophisticated instrument for those testees who have been identified with any concerns in their visual functions. The American Association for Pediatric Ophthalmology and Strabismus (AAPOS) states that vision screening is a practical solution that allows more children to be checked, with the fact that only about 2 to 4 percent of children have an eye problem. A pre-screening phase could save considerable amount of healthcare resources unnecessarily required and speed up the general screening phase.

Certain improvement and enhancement of standard vision screening systems on the market may be done. Currently available vision screeners are bulky, costly, and most importantly they are usually examiner-required and applying the traditional reporting procedures, e.g. oral answering of orientation or hand gesture from the testee. Communication between an examiner and a testee might introduce some misunderstanding and misinterpretation during the test process and/or human errors during the recording process. A more intuitive and error-free reporting procedure should be designed and implemented for improving the reliability and effectiveness of the vision screening system. A self-test procedure may enhance the efficiency in a vision screening test. In a self-test procedure, the feedback and answers of a testee may be recorded through two common techniques. One technique is based on the voice recognition. A testee reports her/his answers orally in a controlled acoustic environment under certain constraints. A major disadvantage of such a setup is that only one screening test may be carried out at one time in a controlled environment. Another technique is based on some manual input manipulation. A testee reports her/his answers through a manual input interface, e.g. an answering box, a keyboard, or a joystick (Johnston, 1968; Menozzi, 1995; Bach, 1996; Hoffmann et al., 1997; Gofin et al., 1991). A big challenge or concern of such a setup is that the manipulation is usually done under a blindfold condition. A testee gazes into the vision screener and keeps her/his fixation of various vision test charts presented inside the screener throughout the whole screening test in order to keep good control of the lighting conditions to the eyes. Therefore, a testee operates the input device without visual feedback of the manipulation. Accuracy of the motor action may be affected with the lack of visual feedback of the manipulation. Therefore, faulty inputs may be expected in such conditions and may further affect the vision screening results.

In the present screening system, we have considered the suitability of various pointing devices for blindfold operation. In a previous study, six commercial computer input devices were evaluated experimentally (Huang and Menozzi, 2013.) The evaluation consisted in an experimental assessment of pointing accuracy and in recording subjective preference while using the devices under similar conditions as in a self-test vision screening test. A joystick, a gamepad, a trackball, a external track pad, a notebook track pad, and a PC mouse were evaluated. Highest pointing accuracy was achieved when a joystick was used. In the subjective ranking, the gamepad and the joystick achieved the best and the second best rank respectively whereas the trackball was the least preferred device. Using the joystick, 97% of pointing trials occurred in the correct direction. If only diagonal orientations are considered, the rate of correct pointing trials increased to 99.5% in the joystick. Based on the findings, a hand-held joystick turned out to be the most adequate input device in a blindfold pointing task.

As for vision screening, required accuracy in pointing depends on the type of vision test. When testing for visual acuity following the ISO 8596:2009 (2009) standard procedure, Landolt rings in eight different, equidistant distributed orientations are presented. Therefore, pointing orientations and the detection of pointing implies an accuracy of at least ± 22.5°. As by experience, responses to diagonal orientations are considered as more complex than responses to orthogonal (horizontal and vertical) orientations, some acuity tests only orthogonal oriented targets, e.g. Snellen E, are used. Therefore, pointing and detection of pointing orientation may occur at an accuracy of ± 45°. Other vision screening test may require a lower accuracy, e.g. two orientations, or a higher accuracy, e.g. 15 orientations when testing color vision by means of the Farnsworth - Munsell D-15 test.

A general vision test includes a series of visual acuity test, color vision test, stereo vision test, peripheral vision test, and contrast vision test. Depending on the targeted market needs and the screening system providers, various vision test charts and test procedures are applied and adapted. For example, in a visual acuity test a testee is required to report the opening orientation of a Snellen E, later in a color vision test he/she is instructed to identify the number recognized on an Ishihara Plate, and so on. Also, various types and forms of the vision test charts are chosen and mixed up in the test series. Considering several vision tests and different test procedures are included in a test series, the explanation and instruction of every task and adaptation time required may result in a long test duration. A more systematic test procedure which considers ergonomics and optimization of the test workflow could reduce the test duration as well as the user load. In the present vision screener, we have aimed to simplify the test procedures and complexity throughout the various vision tests.

One innovative design is focused on reducing the amount of required test trials for each test condition. In such a general vision test, we have selected the most relevant types and ranges of tests which are sufficient for a coarse filtering phase of a vision screening. For example, in a visual acuity test, we have included five visual acuity levels starting from decimal acuity 0.5 and up to 1.25. And for each acuity levels, we have presented four visual targets. Similar principles are applied in other vision tests in the present system in order to reduce the total trials and therefore minimize the test duration.

Another innovative design is focused on the vision test charts used for different vision test types. Different from the traditional test charts and procedures, we have evaluated and implemented newly designed test charts in the present screener. The concept of our idea is to provide the testee a consistent test procedure throughout the whole test series. Therefore, we have investigated on the individual vision test principle and created new test charts all in a similar form. For example, in the color vision test applied in our screener, a testee is presented by a set of

Landolt rings and she/he is required to detect the opening orientation of the Landolt ring, as in other vision tests included in the system.

In the present study, we have established a fully automatic self-administrative vision screener. The system is competitive, stand-alone, user-friendly with easy access, and a portable device for daily healthcare use, as well as for large-scale screening application. Its ergonomic human-computer-interface design can be easily adapted by all users. The consistent test procedure is rather intuitive and error-free, and no examiner or assistant is required. The customized vision test charts and input interface have reduced test duration and eased the required efforts and load of the testee. Such a computerized system should further enable a human-error-free service and could provide its user various possibilities in assessing and using the screening results as preferred.

2. METHODS

A fully computerized screening system has been designed. Considering the large number of patients in occupational health, a good system is aimed to eliminate any potential errors in data transcription, to enable supervision by non-experts examiners or even no is supervisor required.

2.1 Vision Tests

The core concept of the innovative design of the vision test charts was based on the concept of same task procedure throughout the test battery. The testee can learn about the reporting procedure which is to point to the opening orientation of the visual target, i.e. the Landolt ring, in the very beginning of the screening test and follow the same policy for all the vision tests. In Fig. 1 to Fig. 4, the customized vision test charts are demonstrated. Please notice that the charts presented have been modified in scale and in color from the original in order to have better presentation.

The visual acuity tests consist of far vision test (5m) for right eye, left eye, binocular, and near vision test (40cm) for binocular. Tested decimal acuity levels include 0.5, 0.63, 0.8, 1.0, and 1.25. The stereovision test consists of two visual depth targets. The color vision test consists of five trials. And the contrast vision test consists of the combination of three contrast levels vs. three target sizes.

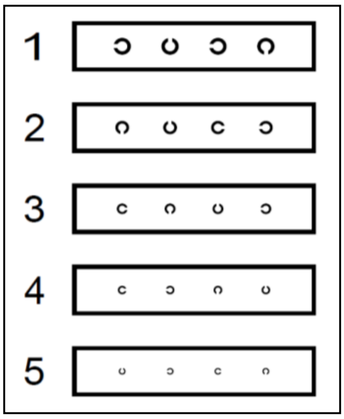

Figure 1: Example of test chart of the visual acuity test. Five acuity levels are included in the test.

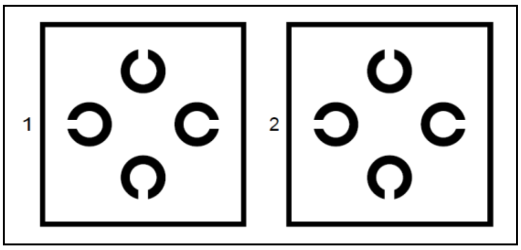

Figure 2: Graphical representation of the test chart used in the stereo vision test. Notice that no stereo effect may be seen on this print-out figure.

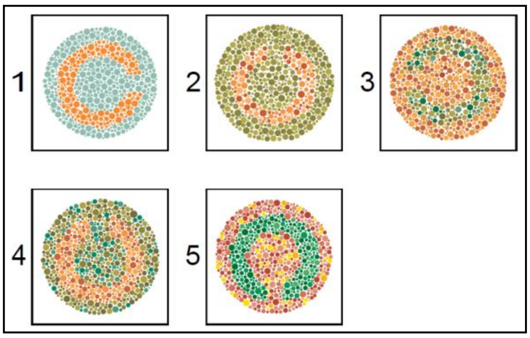

Figure 3: Graphical representation of the color vision test chart.

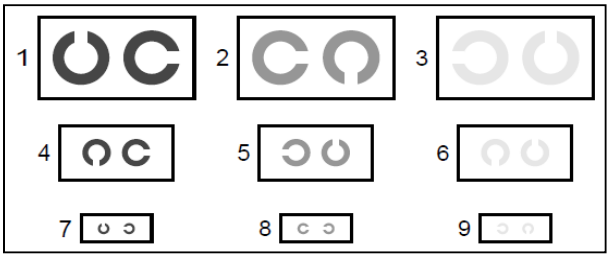

Figure 4: Example of test chart of the contrast vision test. Three optotype sizes and three contrast levels are included.

2.2 Vision Screening Test Installation and Test Procedure

In the fully automatic screening system, there is no administrator required for running the test. The testee could set up the screening environment by herself/himself according to a graphical instruction. The portable system puts all its devices in a suitcase as shown in Fig. 5. The testee can set up the instrument with the ergonomic installation design.

Figure 5: (Upper) The portable screening instrument is fitted and stored in a suitcase. (Lower) The graphical installation guide of the system setup.

After setting up the physical environment, the testee follows the voice instruction of the screening program throughout the test. Currently four different language instructions are implemented (English, German, French, and Italian) in the system. The screening test starts with a general information session and followed by a total of eight vision tests. In the general information session as shown in Fig. 6, a testee is asked for her/his age, the current eyestrain status (strong, medium, weak, or none), the headache status (strong, medium, weak, or none), the eye stress status (strong, medium, weak, or none), and if she/he wears any visual aid (glasses, contact lenses, or none.) In this session the testee is supposed to get used to the operation with the hand-held joystick answering box with a button. The eight vision tests follow the sequence of far vision tests for right eye, left eye, binocular, the near vision test, the contrast vision test, the color vision test, the peripheral vision test, and the stereo vision test.

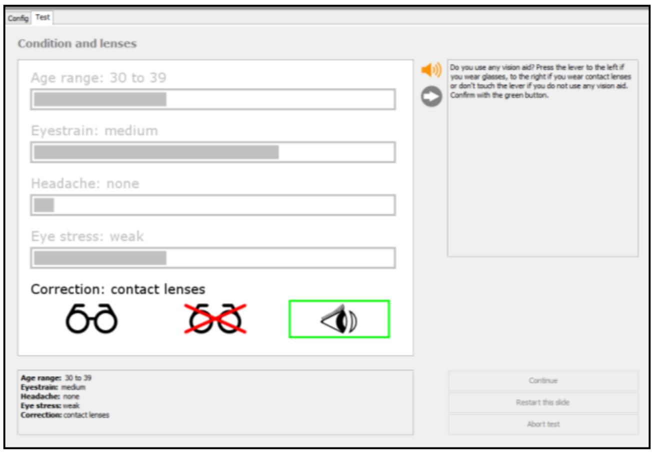

Figure 6: The vision screening program in the first information session.

In the end while completing the last vision test section, the test result is automatically printed out from the printer (as default setting) and/or may be stored and shown digitally. The total test duration is about 10 minutes in average. The pre-test installation time is approximately 5 minutes.

3. RESULTS AND DISCUSSION

Several sets of the vision screening system have been constructed and delivered to companies for a regular-base health campaign application. The screening results are shown in a print-out examination sheet to the testee right after the test is accomplished. The evaluation sheet provides basic test results and information to the testee as shown in Fig. 7. Depending on the purpose and condition, the testee might go for a further follow-up check based on the results. The evaluation sheet lists the following items- 1. Visual acuity right eye (far vision at 5m): < 0.5, 0.5, 0.63, 0.8, 1.0 or 1.25; 2. Visual acuity left eye (far vision at 5m): < 0.5, 0.5, 0.63, 0.8, 1.0, or 1.25; 3. Visual acuity binocular (far vision at 5m): < 0.5, 0.5, 0.63, 0.8, 1.0, 1.25; 4. Visual acuity binocular (near vision at 40cm): < 0.5, 0.5, 0.63, 0.8, 1.0, or 1.25; 5. Contrast vision (far vision at 5m): good or limited; 6. Color vision: normal color vision, possible color vision deficiency; 7. Visual field: left and right normal, right limited, left limited, or left and right limited; 8. Stereo vision: good or limited.

Vision test

15.09.2016 – 16:02

Condition and lenses	
Eyestrain:	weak
Headache:	medium
Eye stress:	none
Correction:	contact lenses

Results	
Acuity right eye (far, 6m):	normal (0.8)
Acuity left eye (far, 6m):	strong limited (0.5)
Acuity binocular (far, 6m):	limited (0.63)
Acuity binocular (near, 40cm):	normal (0.8)
Contrast (far, 6m):	normal
Color vision:	possible color vision impairment
Peripheral visual field:	good left and right
Stereo vision:	normal

Advice

Warning, your far vision acuity is only 63% or less.

See an expert to have your eyes checked.

Figure 7: Example of the evaluation sheet and test results of the vision test.

The newly designed vision test charts have been evaluated carefully and pre-tested repeatedly before being implemented in the screening system. The test results in the present screening system have been compared with several corresponding vision tests carried out with some well-known or standard vision tests (i.e. Rodatest 300/302, ISHIHARA'S TESTS 24 Plates Edition, and LANG-Stereotest with disparities 550", 600", 1200".) Compared with other screening systems on the market, the present system has some main advantages as this is a fully automatic system that requires no additional assistance from any professional. Rarely one can find such a feature among those sophisticated screening systems but only some online vision tests and Apps on the mobile devices. However, those online-based vision tests are not precise as the displayed vision chart details, visual environment, and test conditions are not easy to be controlled.

The portable 13.6 kg screening system fitted in a medium-sized suitcase with wheels is ideal for various applications. For screening campaigns at school or in organizations, for family or individual use at home, it is easy to transport the system to the destination. The estimated cost of a complete system (i.e. including the screening system with the answering box, a notebook with the program implemented, a printer and other accessories) is about 3000 USD. Price-wise this present system is rather affordable both for some screening campaign purpose of larger testee group size and for family-use of few users. The user can easily follow the test procedure with the vocal instruction, and the purpose-built joystick input device enables a fluent and non-frustrating, error-free process in the consistent pointing task. All procedures may be done within 15 minutes from opening the suitcase with the user alone. As the system is fully self-administrative and easy to use, and its affordable cost, it can be promoted as a good healthcare service for everyone. Such a system may contribute to identify some potential eye problems and advise one that should go for further eye-examination in the early stage of some severe eye problems (Sithole, 2016.) As the screening system is fully computerized, one can track one's own historical records, one can compare the results of employees and identify any potential issues of the work environment, etc.

ACKNOWLEDGMENTS

Authors thank Marco Berger and Sandro Ropelato for their consistent and great assistance and support in this project.

REFERENCES

Bach, M. (1996) The Freiburg visual acuity test – automatic measurement of visual acuity, *Optometry and Vision Science*, **73**, 49–53.

Gofin, R. and Falk, M. (1991) Comparison of the automated vision screening test to the Snellen test, *Public Health*, **105**, 139–144.

Hoffmann, A. and Menozzi, M. (1997) Computer-based assessment of visual acuity – technical realization, *Biomedizinische Technik*, **42**, 55–60.

Huang, Y.Y. and Menozzi, M. (2013) Manipulation errors in blindfold pointing operation for visual acuity screenings, *Proceedings of the institute of industrial engineers Asian conference 2013, Springer*.

ISO 8596:2009 (2009) *Ophthalmic optics - Visual acuity testing - Standard optotype and its presentation, International Organization for Standardization*

Johnston, P.W. (1968) Automated vision screening, *Public Health Reports*, **83**, 907–912.

Krueger, H. (1999) Der Betriebsarzt im Spannungsfeld zwischen Arbeitsplatzbegehung und spezieller arbeitsmedizinischer Vorsorgeuntersuchung aus der Sicht eines Arbeitsphysiologen. *Zentralblatt der Arbeitsmedizin* vol. **41**, 361–368.

Menozzi, M. (1995) Using personal computers at screenings of visual functions, *Klinische Monatsblätter für Augenheilkunde,* **206**, 405–408.

Sithole, H.L. (2016) A situational analysis of ocular health promotion in the South African primary health-care system, *Clinical and Experimental Optometry,* doi: 10.1111/cxo.12452.