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Vision Problems In Ecuador: Developing A Clinical Trial to Test Visual Acuity In Rural Populations

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Vision Problems in Ecuador; Developing a Clinical Tool to Test Visual Acuity in Rural Populations

by

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ABSTRACT

In many developing countries, access to medical care and screenings are difficult, and this is especially true for countries with large rural populations, such as Ecuador. There are many groups and non-governmental organizations (NGOs) that contribute time and money to educational systems and other basic infrastructure, but not necessarily medical screenings. In the case of eyesight, without proper screening an individual may fall behind academically or even withdraw from education simply because they cannot see. The simple addition of corrective lenses could be the difference between a life of poverty, and a life of wellbeing for many of these individuals. Visual acuity is a good indicator of eye health, and can be used to quickly screen large populations and identify those with vision problems. Working with Dr. Kass we have developed a program that uses an "open door" method to determine visual acuity. The acuity results from this program can be compared to results from a standard Landolt C eye chart to determine if the program accurately predicts visual acuity. Ecuador is an excellent country to use as a trial for this program, and successful implementation can lead the way for implementation in other countries.

Acknowledgements

I would like to thank all of my committee members their assistance and dedication to this project, specifically Dr. Kass for his consistent support. I would also like to thank Andrew Wilson, Jordan Servetas, and Lindsey Gori, for their collaboration in both writing and help with citations. Finally, I would like to thank Rose McGlauflin for her encouragement and commitment; you've been a huge help this year, and your support means a lot.

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I. Introduction

This thesis is focused on designing a program to test visual acuity. In order to accurately assess visual acuity, an understanding of the function and structure of the eye is essential. Additionally, there are many tests and vision charts that are currently in use, and these will be discussed as well as the benefits of testing using the open door program.

A. Eye Development

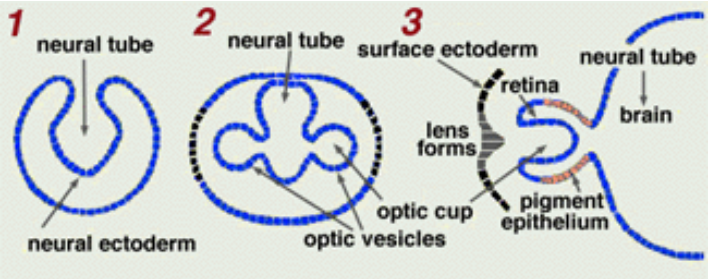


Figure 1.1 Development of the Embryonic Mammalian Eye, from http://www.daviddarling.info/encyclopedia/R/retina.html

The embryonic vertebrate eye is derived from the neural tube, and two invaginations, partially from the diencephalon. These outcroppings are called the optic vesicles, and fold in on itself to become optic cups. The inside of the optic cup develops into the retina, and the outer wall gives rise to pigmented epithelium. The lens forms from epidermal ectoderm that is over the surface of the optic cup. (Fig 1.1) The optic nerve is also formed from an outcropping from the diencephalon, whereas the sclera is derived from the neural crest cells. (Foster R. E. et al. 1982)

The ganglion cells of the eye develop, then the photoreceptors. Nerve cells are formed from the many neuroblasts that are present. The fovea develops last, and consists of a thicker nuclear layer with developing cone cells. The ganglion cells that cover this region migrate outward for cone photoreceptor formation. These photoreceptors will rearrange and change shape for a period that can last up to four years after birth (Kolb et al. 2007)

B. Eye Anatomy

The eye is the organ responsible for vision, and the detection of light is converted to an electrochemical nerve impulse. The eye has several major structures, which all function in either the focusing of light waves, or the transmission of nerve impulses. (Fig. 1.2) The eye is used to collect light from the surrounding environment, and after being converted to an electro-chemical nerve response, the organism can use it to interpret its surroundings. Eyes range in complexity from some very simple "eyes," as found in the skin of drosophila larvae that are very sensitive to blue light, to complex mammalian or avian eyes such as the multiple fovea eyes of hawks and other avian species.

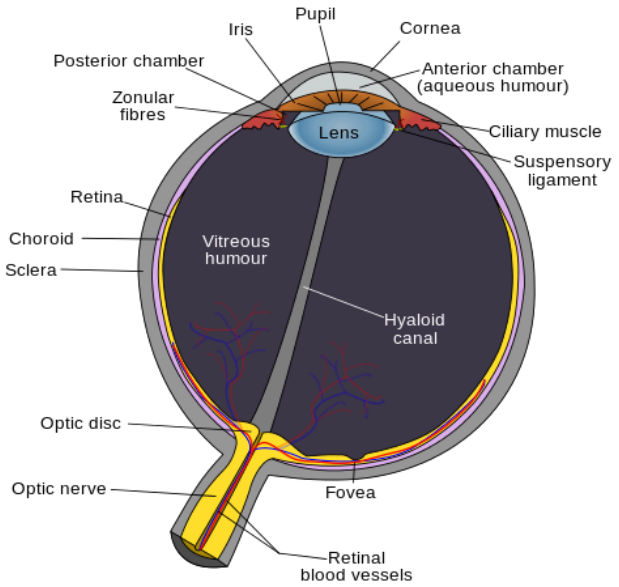


Figure 1.2 Anatomy of the Human Eye from http://www.redorbit.com/education/reference_library/health_1/human-anatomy/1112648956/zonules-of-zinn/

There are two main photoreceptor cell types in the eyes, rods and cones. Rods are photoreceptors that function in lower light than cones, and function in peripheral vision. Cones are photoreceptors that are concentrated in the fovea of the eye, and function in visual acuity and color vision. Although the eye is a complex organ, it is comprised of several basic components that are fairly well conserved among vertebrates. These basic structures are; fovea, lens, iris, optic nerve, pupil, and retina. (Fig 1.2) (Campbell, and Reece 2002.)

The fovea is a small pit in the rear of the eye that has the densest area of cones in the eye. The fovea is responsible for sharp vision, and is required for sharp central vision. This type of vision is called foveal vision, and is used in tasks such as reading, vision tests, and anything that requires focusing on fine details. The lens is transparent, and has three layers; the lens capsule, the lens epithelium, and the lens fibers. The lens is able to change its curvature to change the focal distance and focus light on the retina and the fovea. The iris is a small circular structure that controls the diameter of the pupil by smooth muscle contraction, and thus the amount of light that enters the eye. The optic nerve is the area where a visual stimulus, after being converted to an electro-chemical signal by the rods and cones, leaves the eye and travels to the brain where it is interpreted. The pupil is the hole in the center of the eye that allows the passage of light. It is ridged by the iris, and will change in diameter to limit light. Finally, the retina is the light sensitive layer at the rear of the eye that is lined with rods and cones (Kolb et al. 2007.)

C. Visual Transduction

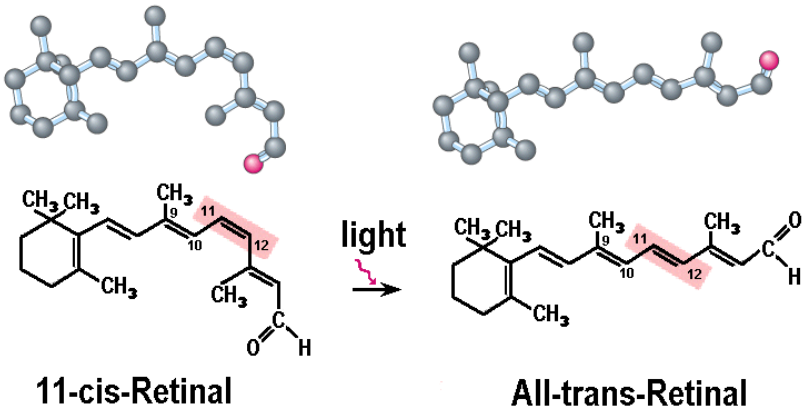


Figure 1.3 Conversion of 11-cis Retinal to all-trans retinal. From Lehninger Principles of Biochemistry, 5th edition

Phototransduction is the process by which light is converted to electrical and chemical signals to be interpreted by the brain. Essentially, when light enters the eye, in the form of photons, it strikes a photopigment, like rhodopsin. Rhodopsin is found in the

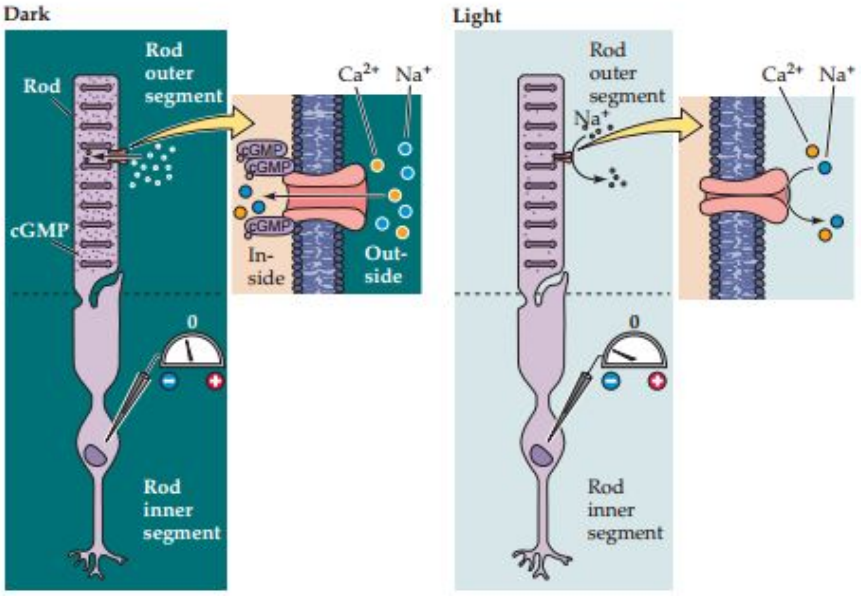


Figure 1.4 Phototransduction Pathway (Purves, 2001)

Rods, and absorption of a photon activates rhodopsin, which causes the conversion of 11-cis Retinal to all-trans retinal. (Fig.1.3); (Wang et al., 1994). This structural change

initiates a biochemical signal cascade, activating transducin, an intracellular messenger, which activates a phosphodiesterase that hydrolyzes 3',5'-cyclic guanosine monophosphate. (Fig 1.4) This hydrolysis of cGMP reduces the number of molecules that can bind to sodium channels on the photoreceptor cell, which results in ion channel closure and hyperpolarization of the cell membrane. (Purves, 2001). Photoreceptor cells are unique because they depolarize in the absence of stimuli. When the cell membrane becomes hyperpolarized (in light), it causes a nerve impulse to be sent. This impulse is interpreted by the brain as a visual stimulus.

D. Visual Acuity

Visual acuity is the ability to distinguish fine details, and is actually a property of cone cells. (Kolb et al. 2007). Rod cells can play a part in visual acuity also, but visual acuity is highest in the fovea (known as foveal vision) and the concentration of cones is highest in the fovea. Essentially, visual acuity it is the ability of an individual to visually distinguish a gap in a line. A person with exceptional visual acuity would be able to distinguish very fine details, and may have no issues reading this text from 15 feet away, whereas an individual with poor visual acuity may need reading glasses to decipher this text. This distinction forms the basis for clinical acuity research. (Kolb et al. 2007).

Visual acuity is an excellent indicator of eye health, and large discrepancies in acuity values can indicate impairment in the visual system. Two of the major medical factors that can cause a decrease in visual acuity are astigmatism and refractive errors. Astigmatism is caused by an irregular curvature to either the cornea or the lens, which causes light to be focused incorrectly. (Fig 1.5)

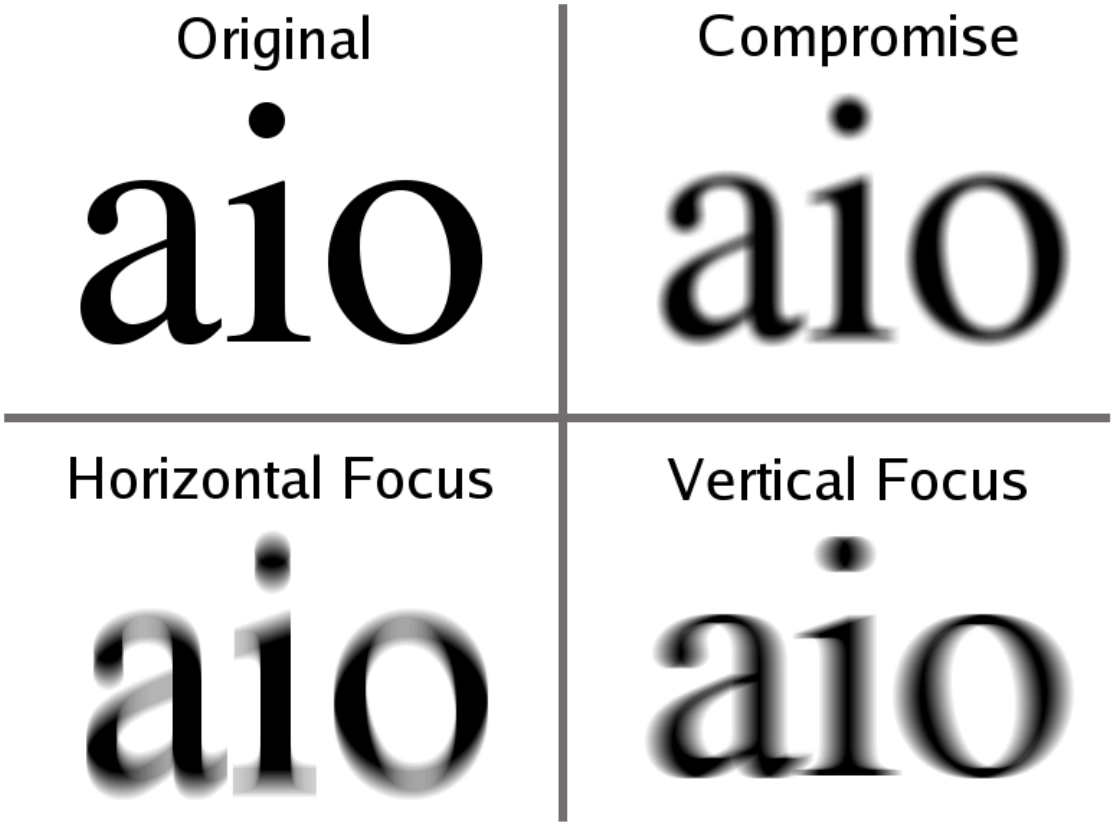


Figure 1.5 Demonstration of Astigmatism errors. These are the 4 types of errors found in astigmatism, and are how a person with the specified astigmatism error would see.

Refractive errors also cause incoming light to be focused incorrectly, but occur at the retina rather than the cornea or lens. Refractive errors can be broken up into three types: Emmetropic, Myopia, and Hyperopia. An eye with no refractive errors is know as Emmetropic. Myopia and Hyperopia are more commonly known as nearsightedness and farsightedness, respectively. These occur when the retina has either too much curvature, as in Myopia, or too little curvature, as in Hyperopia. In nearsightedness the person will not be able to see far away, but will have no issue seeing close objects, the reverse is true for farsightedness. These three conditions (Myopia, Hyperopia, and Astigmatism) can

easily be improved with corrective lenses. Other non-medical factors that can affect visual acuity are pupil size, stimulus intensity, stimulus duration, and eye movement. These are all confounding variables that affect the ability of the photoreceptor cells to receive the stimulus. These factors require special consideration in designing tests to measure visual acuity, as any deviation from standard conditions can cause errors in acuity measurements.

There are 4 types of tests that can be used to assess visual acuity: Detection, Recognition, Resolution, and Localization. A Detection test simply looks for the perception of the presence or absence of stimuli. A recognition test is a form of those most commonly used in testing visual acuity; it simply looks for recognition of characters or shapes (Fig. 1.7). A resolution test is used to test for pattern recognition (Fig. 1.8), for example, the ability to discriminate between two dots, or the distance that must exist between two lines for them to be seen as separate, etc. Finally, localization tests determine the subject's ability to discriminate a small displacement or discontinuity (Fig 1.9). For example, one may be asked to determine where a break occurs along a line. This type of measurement is called Vernier acuity, where discontinuity is specified in terms of its angular size (Kolb et al. 2007).

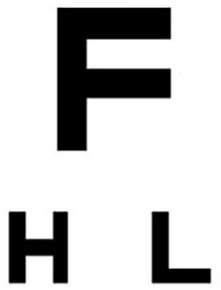


Figure 1.6 Recognition test: Naming the test object, in this case, letters (Snellen) (Kolb et al. 2007).

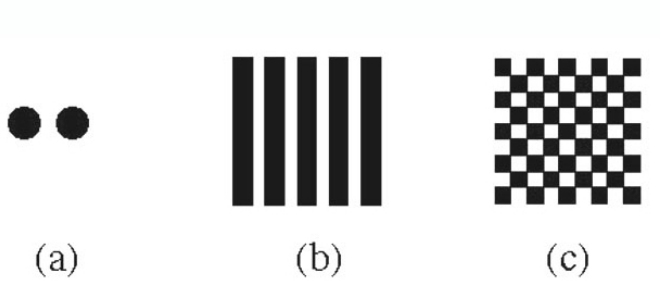


Figure 1.7 Resolution acuity tests: (a) dots (b) grating (c) checkerboard (Kolb et al. 2007).

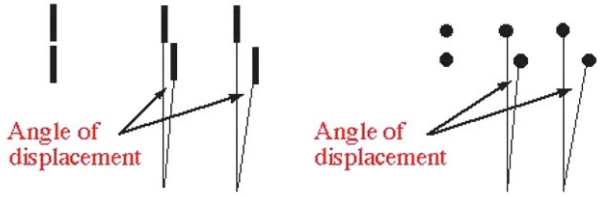


Figure 1.8: Localization acuity test: this is an example of Vernier acuity (Kolb et al. 2007).-

E. Global Health

Public healthcare is a dynamic issue that affects every country in the world, inculding first world countries. It is no question that there are abundant deficiencies in global health, specifically in many developing countries. The issue arises not due to a lack of technology, but due to a lack of resources; this harkens the phrase "We have the technology, but I don't want to spend a lot of money." There are hundreds of millions of people in the world dying from curable or preventable diseases. Their fates could be

avoided if these populations would have access to either medical care or preventative measures. In 1990, the United Nations created a scale that is used to measure overall health in a country. This is called the “Human Development Index” or HDI. (International Cooperation United Nations PAHO/WHO, 2009) It is simply a numerical value ranging from 0.0 to 1.0. The Human Development Index is a composite of life expectancy, education, and income indices, and is used to rank countries into four tiers of human development. (Fig 1.9) The Human Development Index can be used to compare countries, and in this case we can see that Ecuador is ranked in a higher tier of Human Development.

Life Expectancy (LE) Index (LEI) $= \frac{\mathrm{LE} - 20}{85 - 20}$

Expected Years of Schooling (EYS) Index (EYSI) $= \frac{\mathrm{EYS}}{18}$

Mean Years of Schooling (MYS) Index (MYSI) $= \frac{\mathrm{MYS}}{15}$

Education Index (EI) $= \frac{\mathrm{MYSI} + \mathrm{EYSI}}{2}$

Income Index (II) $= \frac{\ln(\mathrm{GNIpc}) - \ln(100)}{\ln(75{,}000) - \ln(100)}$

The HDI is the geometric mean of the previous three normalized indices:

$$\mathrm{HDI} = \sqrt[3]{\mathrm{LEI} \cdot \mathrm{EI} \cdot \mathrm{II}.}$$

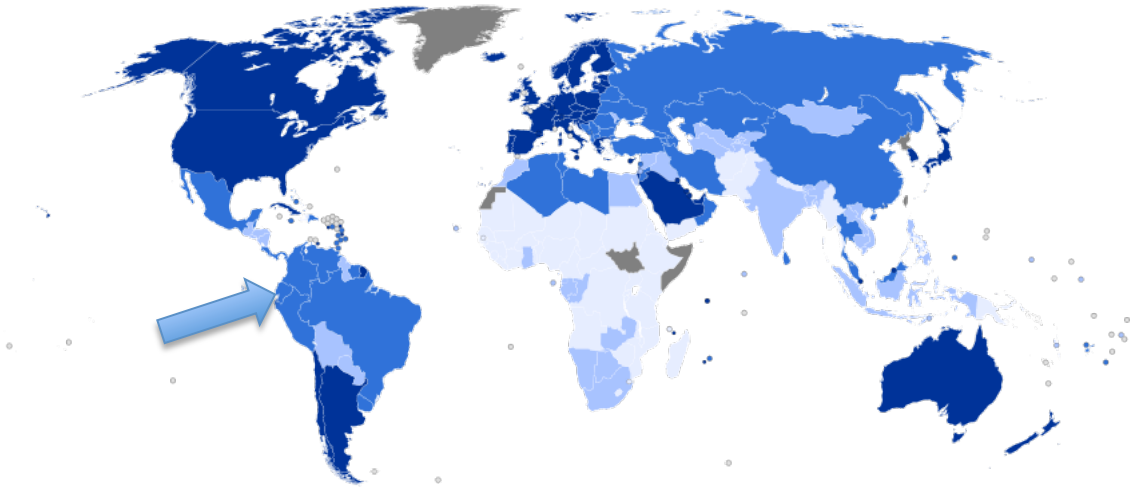


Figure 1.9: This is a composite map showing the tiers of the human development index. The darker blue is used to indicate a higher HDI, whereas the lighter blue indicates a lower HDI. As can be seen from this map, Ecuador is not ranked in the lowest HDI category, but rather resides closer to the top. From http://hdr.undp.org/en/countries

F. Vision Health Globally

Vision is one of the most important aspects of learning, and can be the difference in terms of poverty or well being. The World Health Organization breaks down the current worldwide state of eye health as follows: There is estimated to be 285 million people worldwide who are visually impaired. Of these, 39 million are blind and 246 million have poor or uncorrected vision. Uncorrected refractive errors are the main cause of moderate to severe visual impairment, corresponding to about 80% of all visual impairment ("Visual Impairment and Blindness." *WHO Aug. 2014)*. With proper healthcare, these refractive errors can be easily prevented or corrected. In the pediatric population, an estimated 19 million children below the age of 15 are visually impaired, and 12 million children have refractive errors. Economically, about

90% of the world's visually impaired live in low-income settings, and 90% live in developing countries. There is much room for improvements in these and other healthcare issues.

G. Cultural Constrictions

In some countries, there are cultural barriers that prevent patients from receiving proper treatment. An example of a cultural restraint is Muslim women receiving care male healthcare workers; It is a taboo in Muslim culture for men to receive treatment from women, and women to receive treatment from men. Many times avoiding cultural constrictions can be as simple as asking or patients what *they* prefer. (*Guidelines* . . . *Organizations*" The World Bank) It is important to understand the cultural restraints of the region and population screening will take place in. This will be discussed in further detail in the conclusions (section V.)

II. Methods and Materials

A. Subjects & Pretests

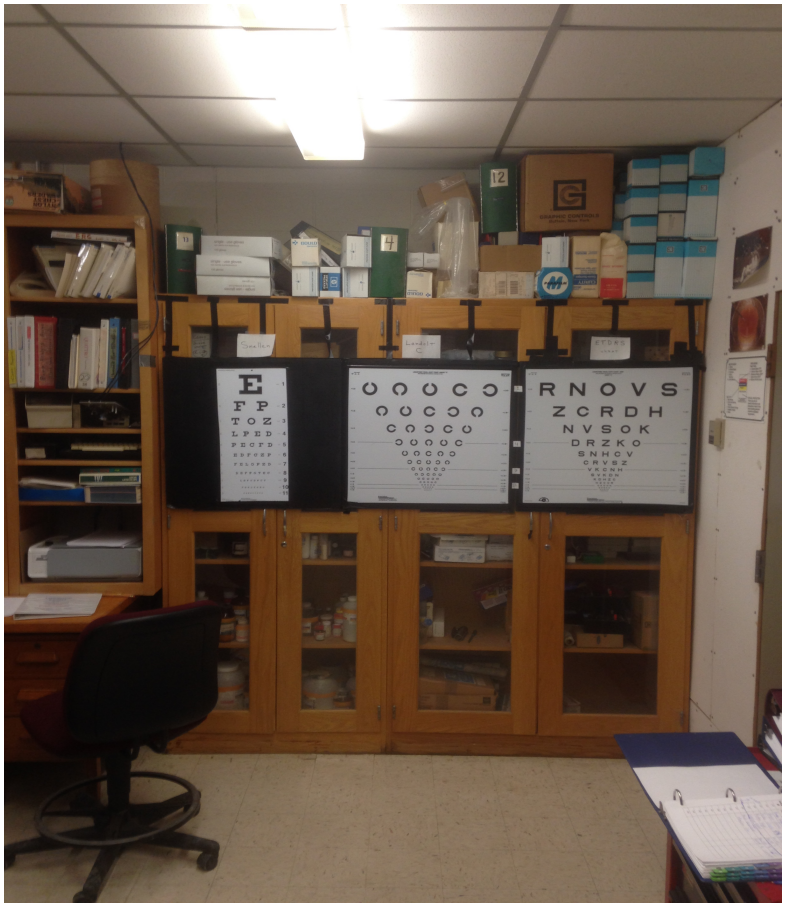


Figure 2.1 View of eye charts from the subject's perspective. On the left is the Snellen chart, in the center is the Landolt C chart, and on the right is the ETDRS chart. Only the Landolt C was used to obtain a baseline acuity for this experiment. Photo credit Andrew Wilson.

All subjects that participated in the experiment were undergraduates from the University of Maine, and the majority of subjects were students in either Dr. Kass' Anatomy and Physiology course, or his Neurobiology course. The students were offered extra credit as an incentive for participating in the experiment. All experiments were conducted in Murray 104a, and subjects were asked to read and sign an Informed Consent form (Appendix B) for further participation. These consent forms were approved by the Institutional Board for the Protection of Human Subjects (Appendix A). After

signing consent, individuals signed in, and were assigned a subject ID number, which was used to identify subjects throughout the process. The subject was then asked to fill out a confidential questionnaire (appendix C & D), This provided in-depth information about their medical history and background, including: age, gender, and other personal information. The subject was then screened for astigmatism and color blindness. The astigmatism-screening test used was a Grid and Radial Astigmatism test (Appendix E & F). The colorblindness-screening test used was the Ishihara Colorblindness test (appendix G). A base-level acuity was then obtained using a Landolt C Acuity chart (Appendix I, and figures 2.1 & 2.3). The Landolt C acuity chart is a chart that is used to test visual acuity. The Landolt C chart is the acuity chart commonly used in Europe, whereas the Snellen eye chart (Fig 2.1, left) is commonly used in the United States. In addition to the Landolt C's popularity, it was selected to be used because it most resembles the computer generated "open door" experiments, described further below. Most people in America are familiar with the Snellen eye chart, as it is routinely used in elementary schools and medical offices to test for visual acuity and visual problems.

To obtain a baseline acuity for this experiment the Landolt C eye chart was used. Subjects would sit 10 feet away from the chart, and read as many lines as possible, beginning with the larger lines and proceeding to the smaller ones (Fig. 2.1).

The subject was assigned an acuity number determined by which line the subject could identify correctly on which part of the circle in the Landolt C the break occurs on (up, down, left, or right.) To this number was added the fractional part of the following line the subject was able to correctly identify where the breaks occur. This was recorded on the subject inventory sheet (Appendix H). For example, if the subject got to line 9,

with all of line 8 being correct, and had 2 of the 5 choices on 9 correct, they would have a score of 8.4. They received an 8 because they got all choices on the 8^{th} line correct, and 0.4 because they had 40% (2 out of 5) of the 9^{th} line correct. This acuity was used as a baseline to compare subjects before the experiment, and was later converted into an acuity expressed in seconds of arc. This will be discussed later, but for the purposes of this experiment this initial acuity will be called the "raw Landolt C acuity" as it is not expressed in viable units.

B. Selecting Subjects:

There were 22 subjects total that were tested, and of these 22, every other subject was used in this study to keep the sample size manageable. In total then, 11 subjects were analyzed to determine visual acuity; 3 males and 8 females. (Table 2.1)

Subject #	Subject ID	Raw Landolt C Acuity	Gender
1	54	9.8	Female
2	68	11.8	Female
3	70	12.2	Female
4	72	11.8	Male
5	74	12.4	Female
6	76	12.8	Female
7	79	11.4	Female
8	81	11.6	Female
9	151	12.4	Male
10	153	11.2	Male
11	155	12.4	Female
Average:		11.8	
Standard Deviation:		0.82	
Range:		9.8 - 12.8	

Table 2.1 Subject Pretest Master Sheet; a list of all subjects used in this study along with their Raw Landolt acuity values.

C. Experimental Setup

After the subjects have completed all pre-experiment procedures, they were taken into a separate room where the actual experiment takes place. The subjects were seated in a chair that was positioned at a fixed distance (10 feet) away from the computer monitor. The subject had a table in front of them with a keyboard, mouse, instructions for running the computer program, and a joystick that was permanently attached to a piece of wood. A joystick was used because it provides subjects with ease of selection, and is more intuitive to use in the dark. Additionally, a joystick allows the program to be used by children, which will be discussed in greater detail later. The wood provided stability to the joystick and allowed ease of use. (Fig 2.2) The experimenter, always myself in this case, then explained the program to the subject, and how to set up the experiments. The steps for setting up the experiment were outlined on the instructions for the program

(Appendix J), but the experimenter reiterated these instructions and walked the subject through each step. For this experiment, the experimenter stayed with the subject while they set up and completed the short practice run. The subject then set up the first experiment, and the door was closed to ensure consistent lighting. All experiments were conducted with the lights off.

After the experiment has been completed, the subject takes a short post-test survey (appendix K). The questions involve perception of movement or blurriness, length of the experiment, and problems associated with the program, etc.

Figure 2.2 View of the expirimental station from the subjects prospective. The computer screen is 10' away from the subject. The keyboard is used for setting up the trials. The jystick is used to select where the subject thinks the break occurs.

D. Experimental design

The program used in these experiments was created by Michael Murphy, Sensory Cyber Systems LLC; Orono, ME. This software program uses an "open door" method, in which a square is presented on the middle of the screen is "broken" (indicated by a small break in the continuity of the lines of the box) on one of the 4 sides of the box. (Figure 2.3). For this experiment, the pixel widths of the openings were manipulated, as well as the side on which the openings occurred. For the purposes of this experiment, the width of the opening was varied from 1 to 6 pixels, and as stated before, the opening occurred on either

the top, bottom, left or right. The subject would use the joystick to select the side that the door appeared on. A fifth choice was available for which the subjects were instructed to select if they cold not see any opening. The subject would select this choice by pressing a button on the joystick. Having 5 choices decreased the probability of error in pure guessing from ½ (last year, only 2 choices available; left or right.) to $1/5^{th}$. (5 choices available.) This will be discussed in greater detail later.

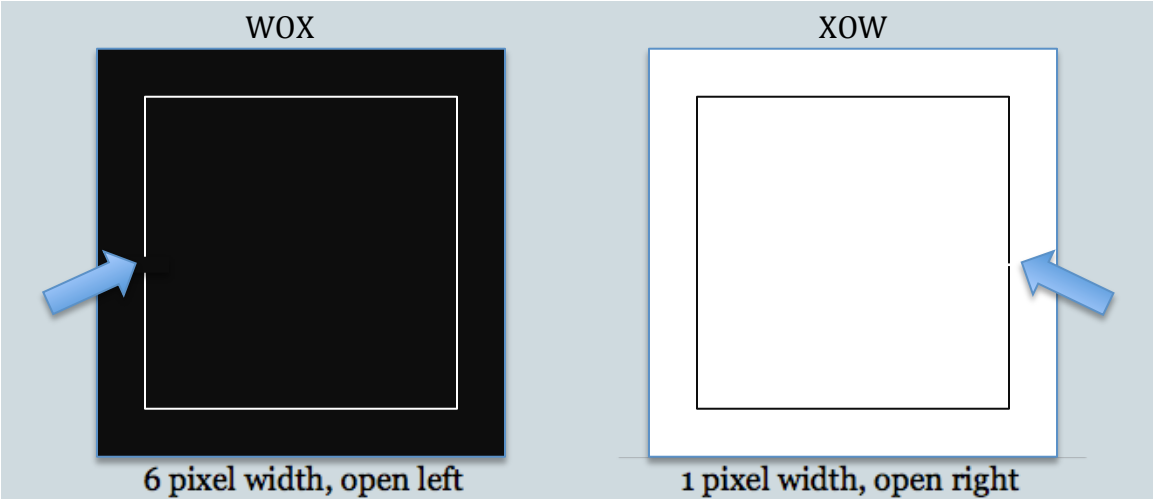


Figure 2.3 Examples of the "open door" as displayed in the computer program. On the left example, "WOX" indicates a white box on a black background; on the right example, "XOW" indicates a black box on a white background. Arrows point to the open door.

The subjects were required to make their selections within four seconds after the box appeared on the screen. If the subject did not respond it would be recorded as "false." Subjects were instructed to not allow this to happen. The program is also designed to record how long it took subjects to respond, and as such, no response appears as "false" within the 4.0-second window.

E. Analysis of Data and Acuity Calculation

In the open door experiment, there were 2 different color combinations; XOW or a black box on a white background, and WOX; a white box on a black background (Fig. 2.3). Additionally, the open door could appear on any of the 4 sides of the box. For the purposes of this experiment, the pixel width associated with a 60% correct response rate was the acuity value. At first 60% may seem arbitrary, but it actually arises due to the number of options subjects have when completing the experiment. For example, as there

are 5 choices, (up, down, left, right, and cannot see) an experiment in which responses are completely random would yield a correct response rate of 20%. Likewise, an experiment in which responses were completely correct would yield a correct response rate of 100%. A score of 100% for acuity for a color combination indicates that the subject could distinguish between the colors every time. 60% is the median between 100% and 20%, and is thus the point at which we define acuity. (Fig 2.4) If the subject has an acuity value that crosses the 60% criterion value more than once, the higher acuity value (lower pixel width) is selected as the true acuity, as this is more likely to be the actual value.

For example, Subject 54 has a calculated black on white visual acuity score of 2.77. This is the corresponding pixel width at which the line on the XOW graph passes the 60% correct response rate. It is important to note that the greater # of pixels indicates a lower visual acuity score, as these individuals are unable to see the smaller openings. The pixel acuity is calculated using Excel, and is based off of the values of the points above and below the (% correct) criterion line from graphs similar to the one above.

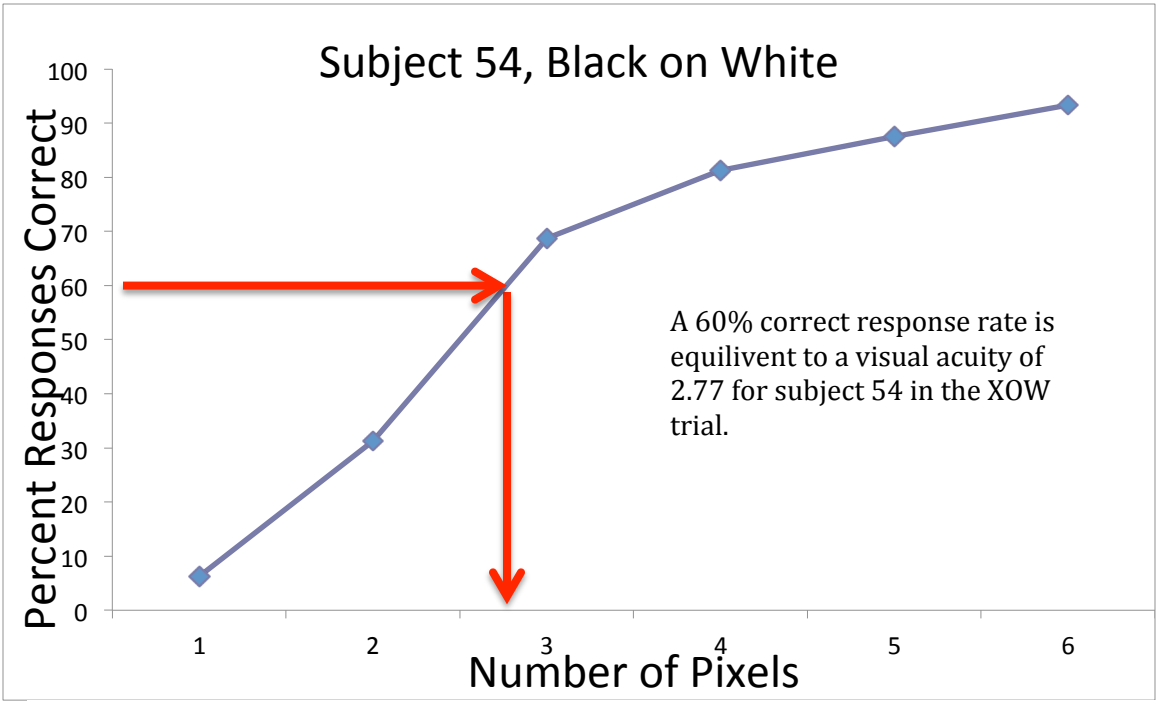


Figure 2.4 Demonstration of how visual acuity is defined, determined, and eventually calculated through these "open door" studies. Further details are provided in the following text.

A number (2.77 for subject 54) can then be converted to an Acuity angle in Arc Seconds. However, for the purposes of this experiment in comparing the effectiveness of the open door method to the Landolt C eye chart, it is simpler to instead convert the Landolt C acuity values into corresponding pixel widths.

F. Calculating Pixel Acuity

Although the open door program expresses visual acuity in pixels, the proper format to express a visual acuity is really in arc seconds, or seconds of arc. Arc seconds is a better way to express an acuity because it is based off of the height of the image (the open door in this case) and the angle that the image enters the eye at a specified distance. This is better than expressing an acuity in pixels because the size of a pixel is not universal for all screens. We calculate the the acuity in arc seconds based off of the following formula;

$$Acuity\ in\ Arc\ Seconds = ATan(\frac{Width\ of\ a\ Single\ Pixel\ (cm)}{Distance\ from\ Subject\ to\ screen\ (cm)}) \times 3600 \times Pixel\ Acuity$$

Equation 2.1 Acuity Angle Equation

Where Pixel acuity is the number calculated from the 60% correct response criterion value. For example:

$$Acuity\ in\ Arc\ Seconds = \tan(\frac{0.025\ cm}{105\ cm}) \times 3600 \times 2.77\ pixels$$

$$Acuity\ in\ Arc\ Seconds = 0.816 \text{ sec of degee arc (3600sec/deg)}$$

The calculation of a pixel acuity from an acuity in arc seconds is very similar, and uses the following equation:

$$Pixel\ Acuity = \frac{Acuity\ in\ Arc\ Seconds}{ATan(\frac{Width\ of\ a\ Single\ Pixel\ (cm)}{Distance\ from\ Subject\ to\ screen\ (cm)})\times 3600}$$

Equation 2.2 Pixel Acuity Equation

This conversion allows direct comparison of the Landolt C acuity chart to the pixel acuity derived from the 'Open door Method".

G. Calculating Landolt C Acuity Angle

If the distance and the acuity width of each line of the Landolt C chart is known, one can calculate the acuity in sec of arc for the Landolt C using Equation 2.3. Notice it is very similar to the equation 2.1, here "distance of subject to screen" is replaced by "size of Gap", and the "Pixel Acuity" value is removed.

By using the chart below, obtained from an article called *Visual Acuity Measurement Standard,* the gap size for the Landolt C eye chart was able to be calculated. This chart is shown below (Table 2.2), and the corresponding values were used to calculate the Landolt C acuity values in Arc Seconds. These gap sizes allow use of the same formula used in the open door experiments to calculate the angle that the subject can perceive on a line.

$$Acuity\ in\ Arc\ Seconds = ATan(\frac{Size\ of\ Gap\ (cm)}{Distance\ from\ Subject\ to\ screen\ (cm)})\times 3600$$

Equation 2.3 Landolt C Acuity Angle Equation

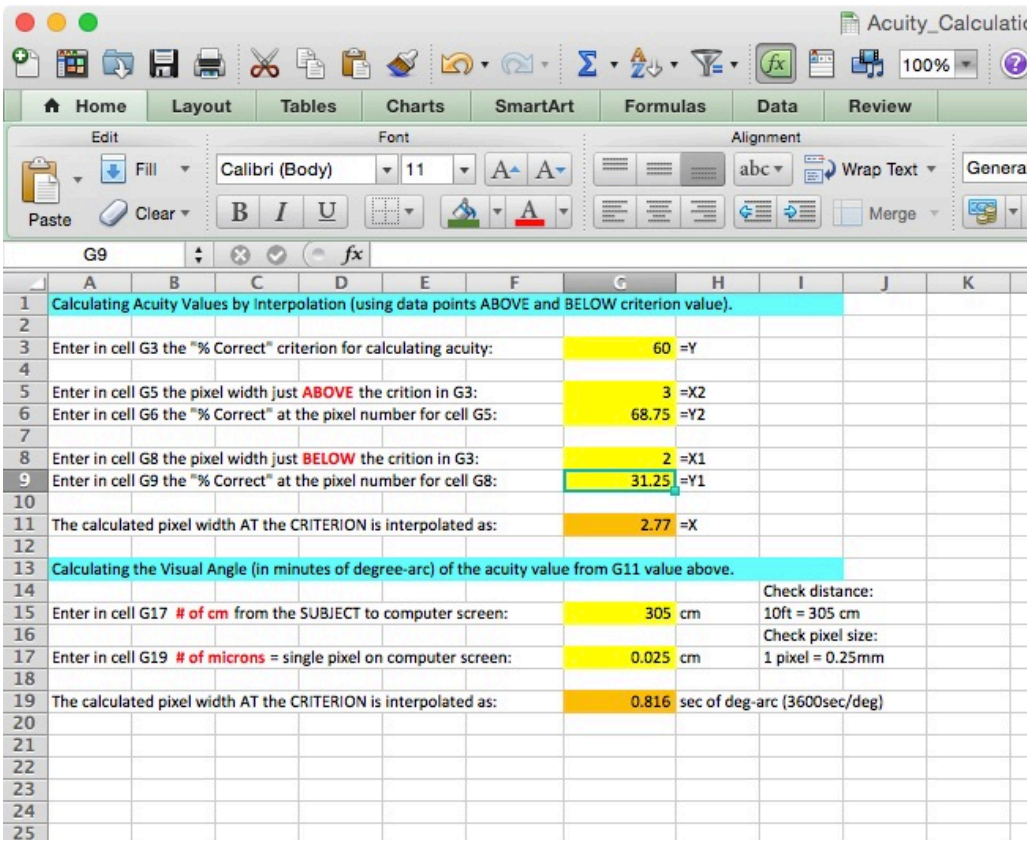


Figure 2.5 Screen shot of the Excel Worksheet used to determine and calculate the visual acuity angles referenced in this study.

Dimensions to be Used for the Preparation of **Landolt Rings** for use at 4 m			**Notations to Designate Optotypes** (in M-units = distance in m at which gap subtends 1 min of arc)		
Size of Gap and Width of Stroke		Outer diameter	Precise M-units	Approximate M-units for clinical use	
min. of arc	mm	mm	Design value	Preferred	Accepted
0.50	0.58	2.92	2.00	2.0	2
0.63	0.73	3.67	2.52	2.5	2.5
0.79	0.92	4.62	3.18	3.2	3
1.00	1.16	5.82	4.00	4.0	4
1.26	1.46	7.32	5.04	5.0	5
1.59	1.84	9.22	6.34	6.3	6
2.00	2.34	11.61	7.98	8.0	8
2.51	2.92	14.61	10.05	10.0	10
3.16	3.68	18.40	12.56	12.5	12
3.98	4.63	23.16	15.92	16	15
5.01	5.83	29.16	20.05	20	20
6.31	7.34	36.71	25.24	25	25
7.94	9.24	46.21	31.77	32	30
10.00	11.64	58.18	40.00	40	40

It is acceptable for the clinician to use approximate values when designating the sizes of optotypes on a chart. For this purpose a tolerance of 0.25 line equivalent (+/- 0.025 log unit, base 10) (approx. 5%) is acceptable.

The chart designer, however, should prepare the optotypes so that their dimensions follow the precisely specified geometric progression, rather than the approximate values used by the clinician. Accuracy within 0.1 line equivalent (+/- 0.01 log unit, base 10) (approx. 2%) is required.

Table 2.2 Landolt C Gap Sizes used in relating the raw Landolt C acuity values to the acuity values obtained from the "open door" studies.

H. Black on White vs. White on Black

For this experiment, subjects sat for two trials; the 1J trial, which is a white box on a black background (aka WOX), and the 2J trial, which is a black box on a white background (aka XOW) (Fig. 2.3). This was done to explore the difference in visual acuity that may exist for the two trials, and use this to determine which is more accurate. There have been other studies that have explored the effect of changes in polarity in reference to visual acuity charts (An inversion of colors). Westheimer et al., 2003 found that using a Landolt C comparison of the normal chart and a reversed polarity chart, the

chart with the brighter letters and dark background corresponded to a greater acuity. (Fig 2.6)

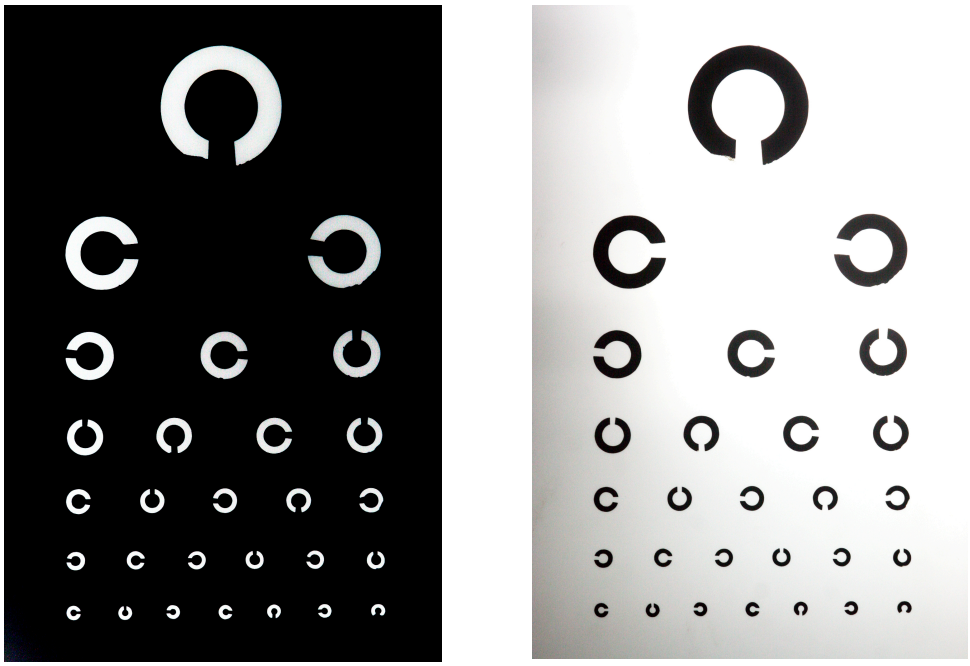


Figure 2.6 Normal Landolt C Chart (Right) and inverted Landolt C Chart (Left)

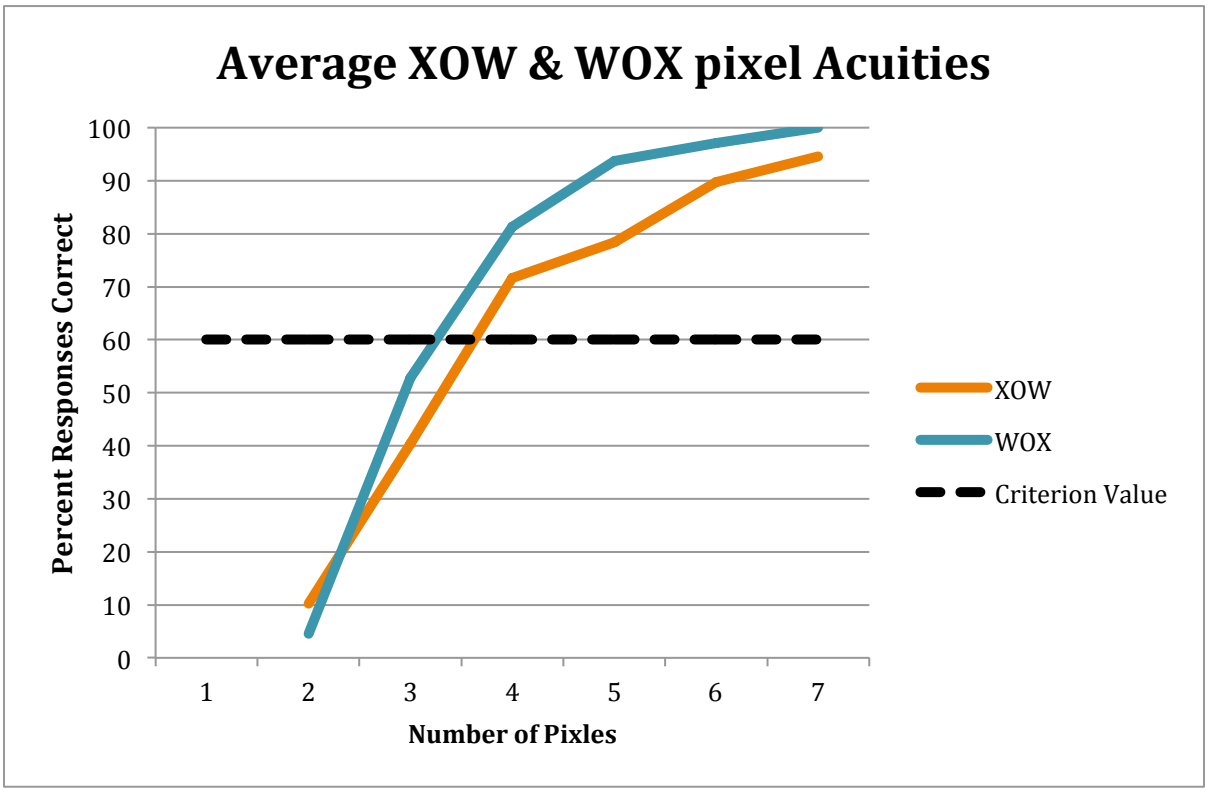
I. Hypothesis:

Both the XOW and the WOX open-door method will accurately predict visual acuity values for subjects that are consistent with current visual acuity calculation techniques, such as the Landolt C eye chart. Differences between XOW and WOX acuities will be explored, as well as their relation to the Landolt C acuity.

III. Results

A. Acuity Differences for All 11 Subjects

The following are the acuity graphs for the 11 subjects depicting the correct response rate vs. the number of pixels. (Graph 3.1, and Appendix L) The criterion values are detailed by the black at the 60% correct response rate. Note the slope of the lines, and the value at which they cross the criterion line; this line denotes the pixel visual acuity.



Graph 3.1: Average XOW & WOX values for all subjects. This graph is a composite of the graphs in appendix L.

Subject ID	Raw Landolt C Acuities	Calculated WOX Acuity (In Pixels)	Calculated XOW Acuity (In Pixels)	Difference in XOW & WOX (In Pixels)	Gender
54	9.8	1.96	2.77	0.81	Female
68	11.8	1.95	2.09	0.14	Female
70	12.2	1.74	1.86	0.12	Female
72	11.8	2.93	3.65	0.72	Male
74	12.4	2.45	2.4	0.05	Female
76	12.8	2.1	2.43	0.33	Female
79	11.4	1.83	2.6	0.77	Female
81	11.6	3.4	4.4	1	Female
151	12.4	3.2	2.93	0.27	Male
153	11.2	1.78	2.33	0.55	Male
155	12.4	2.42	3.66	1.24	Female
	Landolt C Acuity	Calculated WOX Acuity (In Pixels)	Calculated XOW Acuity (In Pixels)	Difference in XOW & WOX (In Pixels)	
Average	11.8	2.3	2.8	0.54	
Standard Deviation	0.82	0.59	0.77	0.33	
Range	9.8-12.8	1.74-3.4	1.86-3.66	0.05-1.24	

Table 3.1 Pixel Acuity Subject Master Sheet

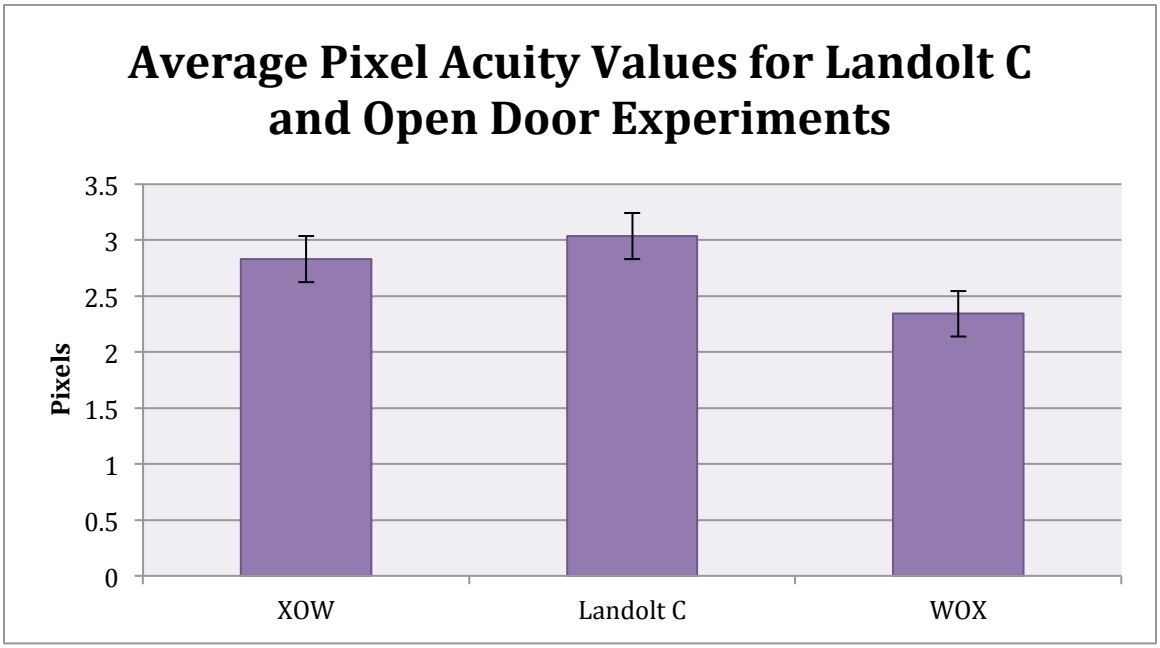
Graph 3.1 is a graph of the correct response rate vs. the size of the gap (size of the open door) in number of pixels. As the size of the gap increases it can be seen that the subject gets more answers correct. When the subject gets approximately 60% of the answers correct (the criterion value), the corresponding pixel size is the pixel acuity. The calculated average values for the acuities (in pixels) for the XOW is 2.82, and for WOX is 2.34. Table 3.1 compares our baseline raw Landolt C acuities with our pixel acuity. Note that a larger raw Landolt C acuity indices the ability to read the smaller lines.

B. XOW & WOX Acuity vs. Landolt C Acuity

How do the visual acuities calculated using the open door method compare with the acuity values predicted from the Landolt C chart? As previously stated, there are two methods of calculating these values: converting both the open door acuity values and the Landolt C acuity values into arc seconds, or converting the Landolt C values into pixel width acuities. Results for both techniques are shown below. (Table 3.2 & 3.3) Additionally, these data are represented by graphs. (Graph 3.12 & 3.13) These graphs depict average differences between the three different tests and the standard error bars for each.

	Landolt C	XOW	WOX
Average (Pixel Width)	3.04	2.83	2.34
Standard Deviation	0.59	0.77	0.59

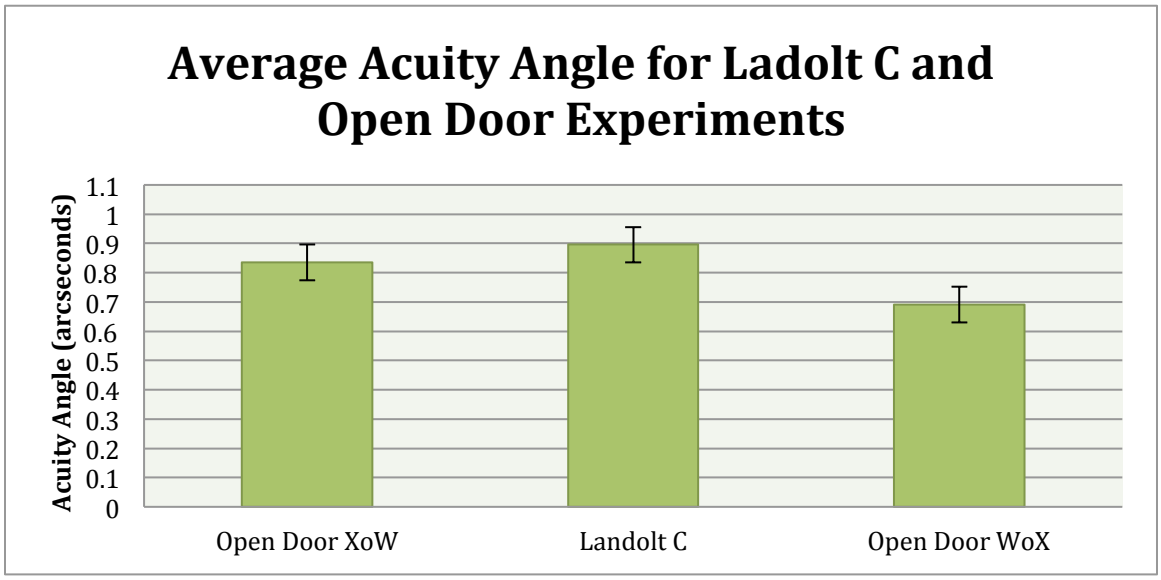
Table 3.2 Average Pixel Acuity and Standard Deviation for Landolt C, XOW, & WOX



Graph 3.2 Average Pixel Acuity values for Landolt C, XOW, & WOX

	Landolt C	XOW	WoX
Average (arcsec)	0.90	0.83	0.69
Standard Deviation	0.18	0.23	0.18

Table 3.3 Average Acuity Angle and Standard Deviation for Landolt C, XOW, & WOX



Graph 3.3 Average Acuity Angle values for Landolt C, XOW, & WOX

Subject ID	Landolt C (Sec of Arc)	Landolt C Calculated Pixel Acuity	Calculated WOX Pixel Acuity	WOX acuity (Sec of Arc)	Calculated XOW Pixel Acuity	XOW acuity (Sec of Arc)
54	1.31	4.45	1.96	0.57	2.77	0.81
68	0.82	2.80	1.95	0.57	2.09	0.61
70	0.82	2.80	1.74	0.51	1.86	0.54
72	0.82	2.80	2.93	0.86	3.65	1.07
74	0.82	2.80	2.45	0.72	2.40	0.70
76	0.65	2.22	2.10	0.62	2.43	0.71
79	1.04	3.53	1.83	0.54	2.6	0.76
81	0.82	2.80	3.40	1.00	4.40	1.29
151	0.82	2.80	3.20	0.94	2.93	0.86
153	1.04	3.53	1.78	0.52	2.33	0.68
155	0.82	2.80	2.42	0.71	3.66	1.08
	Landolt C		WOX		XOW	
Average	0.89	3.03	2.34	0.69	2.82	0.83
Standard Deviation	0.17	0.59	0.59	0.17	0.77	0.22
Range	1.31-0.65	2.80-4.45	1.74-3.40 Pixels	0.513-1.00	1.86-3.66 Pixels	0.55-1.29

Table 3.4 Pixel Acuity & Acuity Angle Subject Master Sheet for Landolt C, XOW, & WOX

There are no statistically significant differences between the open door XOW and the Landolt C measurements, or the open door XOW and WOX data. This information was confirmed by T-tests between all combinations. However, there was a significant difference between the Landolt C and open door WOX, which was confirmed by T-Test. Table 3.5 lists the significant statistical difference of the Landolt C and WoX average acuity angles ($p \leq 0.05$). The two-tailed paired t-test results are shown in Table 3.5.

P-values	XoW	WoX
Landolt C	0.490642775	**0.012581849**
XoW		0.113457738

Table 3.5 P values between XOW, Landolt C, and WOX. Number in bold indicates statistical significance

Graph 3.14 Average Acuity Angle between Landolt C and WOX, statistical significance

These p-values show there is a significant difference in experimental results between the Landolt C and WOX "open door". There were neither significant differences in experimental results between the XOW and the Landolt C, nor WOX and XOW in regards to the acuity angle. These data were obtained from the 11 subjects using the acuity calculation excel spreadsheet. (See Fig 2.5)

IV. Discussion

A. Statistical Significance of Results

As demonstrated in the figures above, a difference exists between the WOX and the Landolt C visual acuity angles, and this is supported by statistical evidence. These results were unexpected, as this demonstrates that individuals have a greater visual acuity for white images on a black background than black images on a white background. The subjects' ability to distinguish small widths on a black background was significantly better, as compared to the Landolt C; At a 95% confidence level the p-values were very low.

In reference to the study above (Westheimer et al., 2003), the greater acuity had a very high significance difference compared to the normal chart ($p < 0.001$). This study also demonstrated that subjects had a better ability to distinguish a bright object on a dark background than a dark object on a white background.

Research on this phenomenon is still ongoing, but the current theory is that a difference in the resolution threshold for the two backgrounds exists. This means there is a physical difference, most likely at the level of the retina, which results in an increased ability to discriminate finer details when the background is black. While the physical cause for this finding is unknown, we can hypothesize that the evolutionary cause has something to do with the need for an increased visual acuity in low light settings. While visual acuity is a property of the cone cells in the fovea (foveal vision) rod cells still play a part in acuity, and it is these cells that would be responsible for this increased acuity (Kolb et al. 2007). Research has shown that differences in visual acuity exist between males and females, (Abramov et al. 2012). This found that females had a better acuity

when discerning shades of green, blue, and yellow, whereas males had better visual acuities when viewing fast-moving objects and details from afar. It would be interesting to see if the acuity differences identified in this study remains consistent between sexes.

B. Use for Screening Children

The open door program has been designed to be simple enough for a child to use. The main limit is the child's ability to understand the concept of selecting the side where the door appears. This means the child must understand the concept of 4 directions: up, down, left and right. This same issue exists in visual and hearing acuity testing, so no greater intellectual capacity is needed for use of the open door program than a standard Landolt C test. Additionally, the open door method is simpler to use than the ETDRS (Fig 2.1, left) or similar chart, as a concept of language or letters is not needed. (Pointer, 2008)

C. Automation

This program has shown immense potential for testing visual acuity, and its disadvantages are few. However, one deficit that has plagued the progression of the program is the amount of time that it takes for a person to move through a trial, and the limited range of pixel widths. Currently, each trial takes about 10 minutes to complete. While one trial is sufficient to determine visual acuity, more may be needed in cases of partial blindness or other extreme visual impairment. Additionally, the pixel range (range of the number of pixels in an open door) of the current program is anywhere from 1-6 pixels. This number is restrictive because it does not accommodate individuals that have

very poor visual acuity, and may not be able to see the widest, (6 pixel) door. Individuals with extremely impaired vision may have a pixel acuity of 20 or 30 pixels. The simple solution for this problem is automation of the program. Automation would consist of additional programming to quickly and accurately determine an individual's acuity. For example, as the program works now, a subject must sit through at least a ten-minute trial, with 96 different box slides. (A single slide consisting of the appearance and disappearance of one box, see figure 2.3) In the automated program, if a subject gets an answer correct, the width of the door would shorten, and likewise if a subject gets the answer wrong, the door would widen. This allows a greater range of acuity values, and cuts down substantially on the time needed to complete each trial. The program would also use real time statistical testing during the trial so that once it has reached statistical significance it will terminate, saving time and eliminating error.

D. Application in Rural areas of Ecuador

Because of the "Right to Health" National Health System, Ecuador has a well-developed healthcare system in populated areas. Unfortunately, the large rural population does not have proper access to this infrastructure due to their location. This places Ecuador in an unusual position as the rural population can have adequate care if they can reach the larger cities. ("Ministerio De Salud Pública El Ministerio." Ministerio De Salud Pblica. N.p., n.d. Web. 18 May 2015.) Volunteers or NGOs (non-governmental orginizations) can use our program to screen these rural populations, and the National Health System will provide for their treatment. Thus Ecuador is an excellent country to

test this program, as diagnosis (identification) is the only step preventing corrected vision.

Ecuador has historically been divided into 4 regions: the Andes, the Amazon Basin, the Coast and the Galapagos Islands. Each region has it's own specific health hazards, including weather and natural events specific to each region. For example, hypoxia and altitude sickness are extremely common in the Andes, whereas venomous animal species and poisonous plants cause many injuries in the Amazon basin. The Amazon Rainforest has many species that pose threats to human health. Additionally, Malaria and yellow fever are also common in these areas, and can be transferred to humans by infected mosquitoes.

Pollution is also an issue in Ecuador, and pollution related diseases have been on the rise. There are high amounts of air pollution in Ecuador, and this has resulted in a rise in air-born illnesses and respiratory problems. ("Dealing . . . . America", 2015.) Access to clean drinking water has also become an issue within the past few decades, and this trend indicates an increase in water pollution and contamination. There also appears to be a lapse in wastewater and sewer treatment, as water borne diseases like cholera have been on the rise. A recent study found that 21.9% of households in Ecuador do not have access to clean drinking water. Additionally, only 48% of households have sewer systems, and only 5% of wastewater is treated. (WHO, The World Bank: Country Cooperation Strategy: "*ECUADOR")*

E. Ecuadorian public health system

The Ecuadorian public health care system was founded in 1967. The Ministry of Public Health is the entity responsible for the regulation and creation of the public health policies and manages the health system and health care plans. The philosophy of the Ministry of Public Health is to "give social support and services to the most vulnerable populations" and its primary goal is to treat and prevent disease with preventive medicine.

("Ministerio De Salud Pública El Ministerio." Ministerio De Salud Pblica. N.p., n.d. Web. 18 May 2015.)

According to the WHO and the World Bank, in the Ecuadorian public health care system; patients are treated in public general hospitals, by both general practitioners and specialists. There are four basic specialties: pediatric medicine, gynecology, clinical medicine, and surgery. Specialty hospitals are also a part of the public health care system, designed to treat chronic diseases or a particular group of the population. For example, oncological hospitals are for cancer treatment, pediatric and gynecologic hospitals, psychiatric hospitals, geriatric hospitals, etc. Additionally, there are private hospitals that cater to tourists and wealthy Ecuadorians, and generally provide quicker, but not necessarily more advanced care. It is important to note that the word "hospital" holds a different meaning outside America and the western world. In America, most view a hospital as a large center where definitive care can be provided on a large scale. In Ecuador, many hospitals would be equivalent in terms of size and scope of treatment as american health centers. In large cites and heavily populated areas "westernized" hospitals exist, and these hospitals are larger and able to provide a greater scope of

practice. However, the majority of hospitals are “basic” hospitals that exist in smaller towns or cities. (WHO, The World Bank: Country Cooperation Strategy: “*ECUADOR”)*

F. Rural communities in Ecuador

Most of the rural communities in Ecuador have a sizable population of indigenous people; there are specialized doctors assigned to these indigenous communities, called also “rural doctors." These doctors run small clinics that meet the needs of patients in the same fashion as the day hospitals in the major cities. The type of care in rural hospitals is different because there is a greater focus on rural medicine, and respect for the indigenous culture and community is of the upmost importance.

By the numbers, 30 percent of the Ecuadorian population receives health services from the Ministry of Public Health (MSP). Private services cover 20 percent. The Social Security Institute covers eighteen percent of the population. Two percent is covered by the Armed Forces, and NGOs (Non Governmental Organizations) cover about five percent. Additionally, there are 980 inhabitants per doctor, as reported by the World Health Organization. (WHO, The World Bank: Country Cooperation Strategy: “*ECUADOR”)*

G. Vision and Hearing Screening in Ecuador

For many Ecuadorians, vision screening occurs at a young age (under 10 years). However, this is in the populated areas of Ecuador. According to the WHO, 67% of Ecuadorians live in an urban environment, and around 33% live in rural or semi-rural environments.

The ability of this 33% to reach effective healthcare is directly correlated to their distance from populated areas. Even when doctors do travel to these areas, they are often preoccupied with more severe cases. There are a few NGOs, such as Unite for Sight, that send doctors to these remote locations to test vision, but this is not efficient, as these doctors end up screening a large number of healthy individuals. A computer generated and easy-to-use visual screening program would allow physicians to focus on a pre-selected group.

V. Conclusion

Figure 5.4 A Student from Ohio University provides care to an Ecuadorian woman in a rural setting. From: https://www.ohio.edu/globalhealth/

Now that I've indicated some applications for this program and evidence of its effectiveness, I will examine more closely implementation in terms of cultural effects and impacts for both Ecuador and other areas.

A. Guidelines For Non-Government Organizations

The World Bank has an excellent publication, titled "Guidelines For Non-Government Organizations" *""*(n.d.): 121-38. The World Bank. Web. This is a guide for NGOs interested in development projects in indigenous or improvised areas. Development projects fall under one of three categories: support (e.g. fiscal, technical, medical,

educational), advocacy (e.g. environment, legal, special interest), and representative. The World Bank puts forth 8 specific guidelines to developing a non-invasive or non-detrimental impact to the culture and people. The guidelines, and the plan for implementation are as follows:

Step 1: Ensure that your objectives and those of the indigenous peoples are the same.

In order for implementation to be successful, we need to be prepared to put the needs of our patients first. In terms of rural and indigenous Ecuadorian populations, this involves research and surveying populations to make sure that they want the care we are providing. Does a community actually want vision screening? Will they accept care, or do they feel like it is being forced upon them. Selecting sites for implementation is our number one priority.

Step 2: Create a representative NGO for the community or join one.

If selecting sites for implementation is our number one priority, then finding cultural representatives from these communities must be our second priority. These representatives serve as more than an interpreter; they are both a voice of the community, and a medium through which the culture and history of the population can be interpreted. Representatives serve extremely important roles ensuring that cultural boundaries are not overstepped, and that the community understands our goals and the process as a whole.

Step 3: Work with the indigenous peoples to help estimate the impacts.

This guideline goes hand in hand with the second. There may be unknown impacts from our testing that we are unable to comprehend. It is important to ensure the process, the program, and the testing itself is as noninvasive as possible. A small amount of harm can negate years of progress and relations. A slow approach, coupled with plenty of time to build rapport with the community is vital for real progress can be made. As stated before, this is specific to each population, and an individualized plan must be made for each community. Some rural areas or towns may accept screening, whereas others may be weary. Thankfully, situations similar to this are very uncommon in Ecuador, as rural populations are generally aware of their healthcare options. However, it is an important aspect that must be kept in mind when implementation is considered in other areas.

Step 4: Help by providing access to information.

This step can be as simple as explaining the benefits of screening, and how we plan to help those who need additional care. This is where partnerships with NGOs, such as Unite for Sight, and the Ecuadorian National Health System come into play. Providing information or access to definitive care is crucial to ensuring a healthy relationship with the community.

Step 5: Assist indigenous peoples to communicate in different media.

This guideline deals with ensuring that the population has a voice, whether it occurs through written or electronic media. As previously stated, it is important for the population to make their own healthcare decisions, and not feel like care is being forced on them.

Step 6: Assist indigenous peoples to understand the powers at play.

Most Ecuadorians are aware of the National Health System, and understand how to seek treatment. As stated before, after patients have been identified as needing treatment, the NHS will provide their care. This was one of the major reasons that Ecuador was selected as a possible site for program implementation. However, many other countries do not have this luxury; ensuring that the community understands the political structure, limits or restrictions of NGOs and similar organizations, and their rights under international law are of the upmost importance.

Step 7: Be sure to understand the nature of traditional knowledge.

This is extremely important for any group or organization seeking to provide medical care, particularly to rural or indigenous populations. Clinicians must make an active effort to not infringe upon cultural and traditional medicine, and must be willing to include it in their treatment. Again, this is not much of an issue in Ecuador, but in other areas it can become a major setback.

In the case of vision screening, it may be as simple as speaking with a religious or spiritual leader to explain what the program is, and what it is designed to do. This is similar to the second guideline, as those familiar with the culture are able to understand when a certain practice or treatment infringes upon traditional medicine.

Step 8: Encourage the inclusion of indigenous knowledge in finding innovative solutions.

This guideline is very similar to the last, and essentially highlights the need for traditional and indigenous knowledge in planning and decision-making. For our purposes it just involves ensuring that decisions based on the care of the populations occurs as the

result of discussion between the populations themselves, and the group or organization providing the care or screening.

B. Solutions to these problems

As stated previously, each country and region has it's own specific challenges in terms of implementation of need based aid. Screening must be done in a way that is non-invasive to communities, and a tough approach to must be taken to prevent harm. This program is useful, but must be used in conjunction with other forms of aid to in order to actually be effective in changing the visual health of a region.

It this thesis, the ability of the "open door" program to accurately screen visual acuity has been demonstrated. The accuracy and speed of this program make it a far better choice than other current methods of vision screening, and accuracy and speed will only increase as the program becomes automated. This program is very easy to use, has been designed to be operated with little to no training, and only requires a laptop for equipment. These attributes allow this program to be used in rural screening, where there is generally a scarcity in time, resources, and personal. As identification is the first step in treatment, with proper use and a well-defined action plan this program can help millions across the world achieve a better life through improved vision.

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VII. Appendices

Appendix A: IRB Form

MEMORANDUM

TO: Leonard Kass
100 Murray Hall

FROM: Gayle Jones
Assistant to the Institutional Review Board for the Protection of Human Subjects (IRB)

SUBJECT: "The PC Monitor as a Visual Stimulator for Educational Studies," #2008-02-06

DATE: April 3, 2015

The Institutional Review Board for the Protection of Human Subjects (IRB) conducted its continuing review of the above referenced project in an expedited review on 6/23/2014. The IRB approved renewal, and the approval period is now through 6/22/2015. The next continuing review of this project must be conducted by the IRB before the end of the approval period. Although you will receive a request for review information approximately 6-8 weeks before that date, it is your responsibility to submit review information before the approval period expires.

Enclosed are approved copies of the consent documents for this project. These consent forms are approved for use through 6/22/2015. **These approved copies must be duplicated and used when enrolling subjects during the approval period.**

Please remember that each subject must be given a copy of the informed consent document. Any unanticipated problems or injury to the subject must be reported to the IRB. Any proposed changes to the research must be approved by the IRB **prior** to implementation. Any significant new findings must be reported to the subject.

If you have any questions, please contact me at 1-1498. Thank you.

Appendix B: Informed Consent Sheet

UMaine Institutional Review Board
Approved for Use Through:

JUN 17 2014

Informed Consent Form

For Subjects 18 years or older participating in this study

You are invited to take part in a research project. It is conducted by or under the direction of Dr. Len Kass, a vision scientist in the School of Biology and Ecology, at the University of Maine.

Purpose of study: To examine the way the eye works and to develop a school science exercise.

What you will be asked to do: You will be asked to look at objects on a wall, several sheets of paper, and on a computer screen. You will be asked to report what you see by responding orally, by marking on papers, or by pressing keys on a keyboard.

Time it takes to complete study: This will take about an hour of your time. After that you have the option to continue with an additional 10-30 minute test. ***You may stop at any time or for any reason.*** This is completely voluntary on your part.

Risks: Except for your time and inconvenience, there are no risks involved with participating in this experiment.

Benefits: You may find this study interesting and educational because we will be testing your very own visual system! The results will help us understand how we use our eyes to see things. Eventually, we also think this project would be of interest for use in Science as well as Science Education classes in various K-16 classroom settings.

Compensation: When applicable, course or educational credit will be given for participation.

Confidentiality: Your identity will be kept confidential. This consent form will be shredded at the end of this study. A number will be assigned to your file containing all of your responses. The results from these studies will always remain confidential, and will be stored indefinitely in the office of Dr. Len Kass, 104a Murray Hall, School of Biology & Ecology, University of Maine.

Contact Information: Contact Dr. Len Kass (ph: 581-2567; email: Len.Kass@umit.maine.edu), 100 Murray Hall, School of Biology and Ecology, University of Maine, Orono, ME 04469 with any questions concerning this research and educational project.

Other Contact Information (and for any other concerns or questions):
Contact Gayle Jones (ph: 581-1498; email: Gayle.Jones@umit.maine.edu), Assistant to the Protection of Human Subjects Review Board, University of Maine, 5703 Alumni Hall, Room 114, Orono, ME 04469-5703, with any questions about all rights as a research participant.

Appendix C: Confidential Questionnaire

Confidential Questionnaire for Vision Tests

Subject ID #: _____ **Age:** _____

Are you (circle one) Right handed or Left handed

Gender: Male or Female

Do you wear corrective lenses? Y or N

If yes, about when did you obtain your most recent prescription lenses? _____

Are you currently wearing (circle one) contact lenses or glasses

Have you ever had corrective eye laser surgery? Y or N

Do you have glaucoma? Y or N

Do you have any of the follow?

Nearsightedness (can see objects up close clearly) Y or N

Farsightedness (can see objects from a distance clearly) Y or N

Astigmatism Y or N

Color-blindness Y or N

If yes:

Red Green Color Blindness (difficulty distinguishing greens vs. reds) Y or N

Blue Yellow Color Blindness (difficulty distinguishing blues vs. greens or yellows vs violets) Y or N

Do you have any other visual limitations or impairments you know of? Y or N
If yes, what are they? _____

Do you have diabetes? Y or N

Do you have a seizure disorder? Y or N

Do you smoke? Y or N

Do you on average drink alcohol more than once a week? Y or N

Do you take any medications? Y or N
If yes, which ones? _____

How many hours on average would you estimate you spend in front of a computer screen each day? _____

Are there any health factors that may affect your performance for this experiment?
Y or N
If yes, what are they? _____

_____

_____

TURN PAGE OVER

Appendix D: Confidential Questionnaire Part 2

Confidential Questionnaire for Vision Tests

Name: _____ Age: _____
(please print)

Do you wear corrective lenses? Y or N

Are you currently wearing those lenses? Y or N

Have you ever had corrective eye laser surgery? Y or N

Do you have any visual limitations or impairments (e.g. color blindness)? Y or N

If so, please explain: _____

Are you (circle one) Right handed or Left handed?

Are you (circle one) Male or Female?

Fitzpatrick Category A (please circle all that apply)

Score	0	1	2	3	4
What are the color(s) of your eyes?	Light blue, grey, or green	Blue, Grey, or Green	Blue	Dark Brown	Brownish Black
What is the natural color of your hair?	Sandy Red	Blond	Chestnut/ Dark Blond	Dark Brown	Black
What is the color of your skin? (Non-exposed areas)	Reddish	Very Pale	Pale w/Beige Tint	Light Brown	Dark Brown
Do you have any freckles on unexposed areas of skin?	Many	Several	Few	Incidental	None

Fitzpatrick Category B (please circle all that apply)

Score	0	1	2	3	4
What happens when you stay in the sun too long?	Painful Redness, Blistering, Peeling	Blistering Followed by Peeling	Burn Sometimes Followed by Peeling	Rare Burns	Never Burned
To what degree do you turn brown?	Hardly or not at all	Light Color Tan	Reasonable Tan	Tan Easily	Turn Dark Brown Quickly
Do you turn brown after sun exposure?	Never	Seldom	Sometimes	Often	Always
How does your face react to sun exposure?	Very Sensitive	Sensitive	Normal	Very Resistant	Never had a Problem

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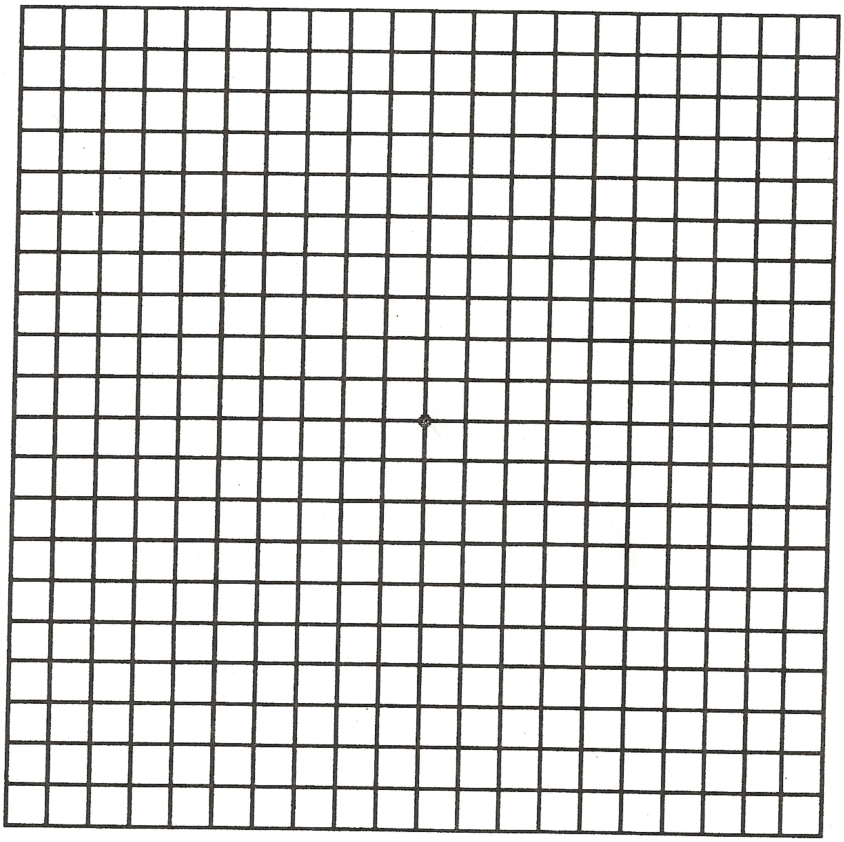
For office use only:

Category A Subtotal: _____ Category B Subtotal: _____ Total Score: _____

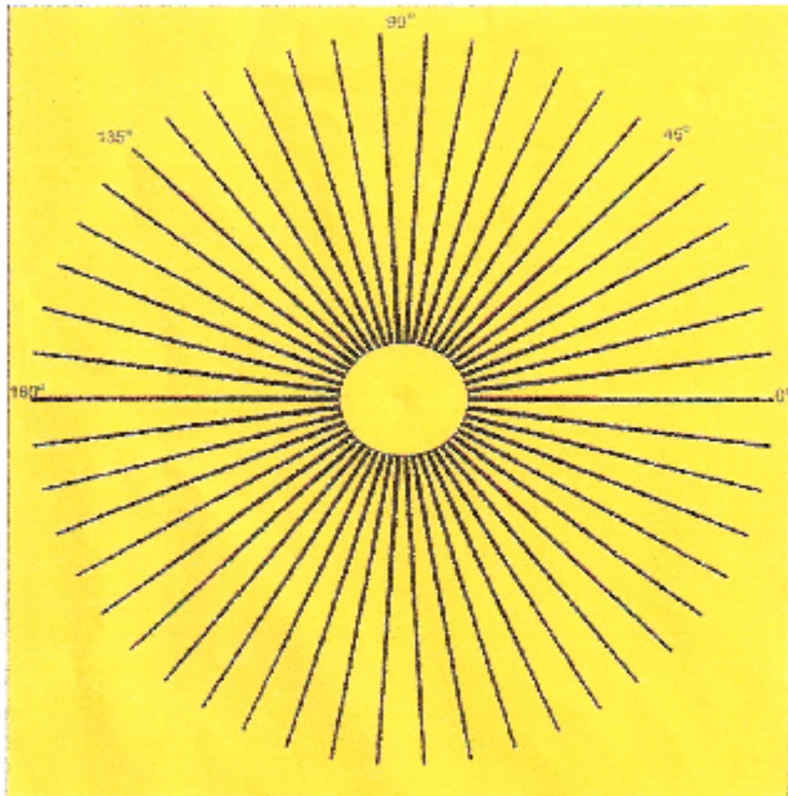
Appendix E: Amsler Grid

AMSLER GRID



1. Test vision with one eye at a time, and use normal glasses for reading.
2. Hold chart at normal reading distance.
3. Stare at central dot and look for distortion or blind spots in the grid.

Appendix F: Radial Astigmatism Test



If you have astigmatism then the axis will show up as distortion in one or several of the rays of the Astigmatic Mirror above. The angle of the major distortion is indicated on the chart.

People with natural clear vision see all the lines in the same thickness and exactly the same spacing between the lines.

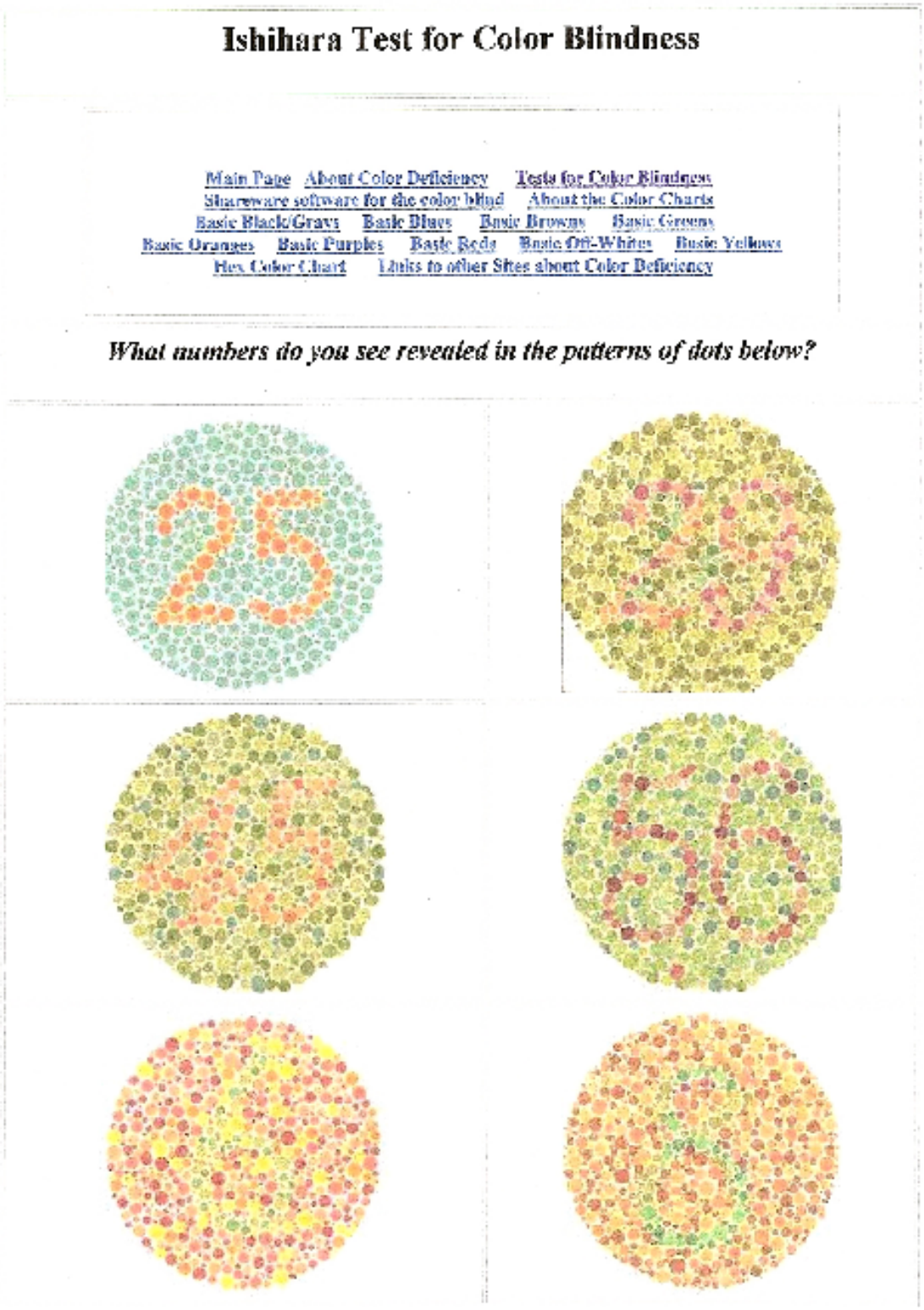
Look at the Astigmatism chart from several distances and notice where the distortion begin and ends. It is possible to have astigmatism only at the near, or only at the distance, or at any place in between.

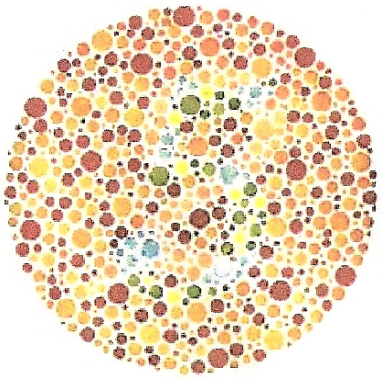
Download the Acrobat file and print a chart in with the background colour you like the best. Set your printer to the highest print quality as possible

The Astigmatic Mirror provide an accurate feedback concerning your astigmatism.

3/24/2008

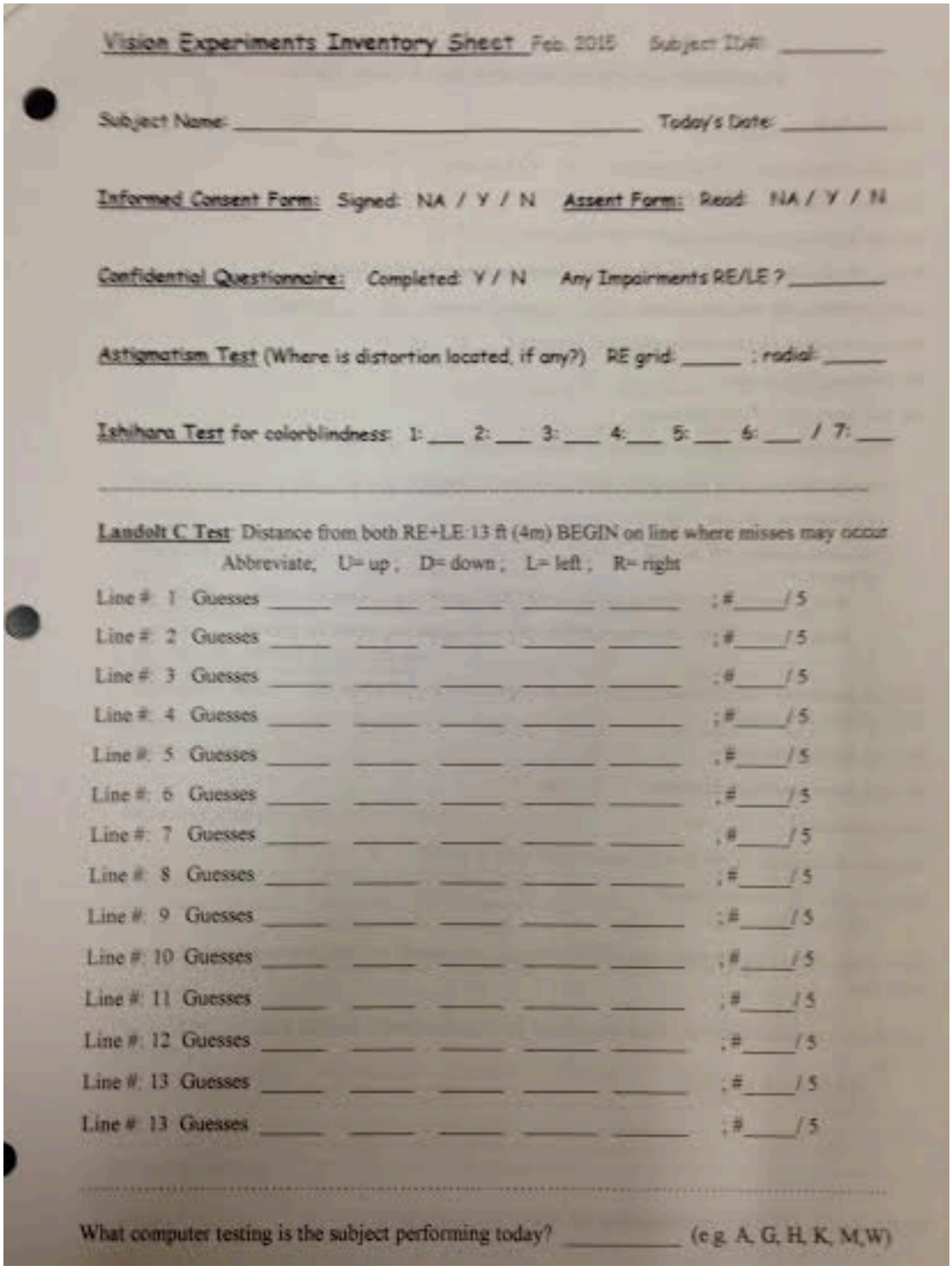
Appendix G: Ishihara Colorblindness Test





The test to the left is simpler. The individual with normal color vision will see a 5 revealed in the dot pattern. An individual with Red/Green (the most common) color blindness will see a 2 revealed in the dots.

Appendix H: Inventory Sheet



Vision Experiments Inventory Sheet Feb. 2015 Subject ID#: _____

Subject Name: _____ Today's Date: _____

Informed Consent Form: Signed: NA / Y / N Assent Form: Read: NA / Y / N

Confidential Questionnaire: Completed: Y / N Any Impairments RE/LE ? _____

Astigmatism Test (Where is distortion located, if any?) RE grid: _____ ; radial: _____

Ishihara Test for colorblindness: 1: ___ 2: ___ 3: ___ 4: ___ 5: ___ 6: ___ / 7: ___

Landolt C Test Distance from both RE+LE 13 ft (4m) BEGIN on line where misses may occur

Abbreviate, U= up ; D= down ; L= left ; R= right

Line #: 1 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 2 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 3 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 4 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 5 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 6 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 7 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 8 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 9 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 10 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 11 Guesses _____ _____ _____ _____ _____ ; #____/ 5

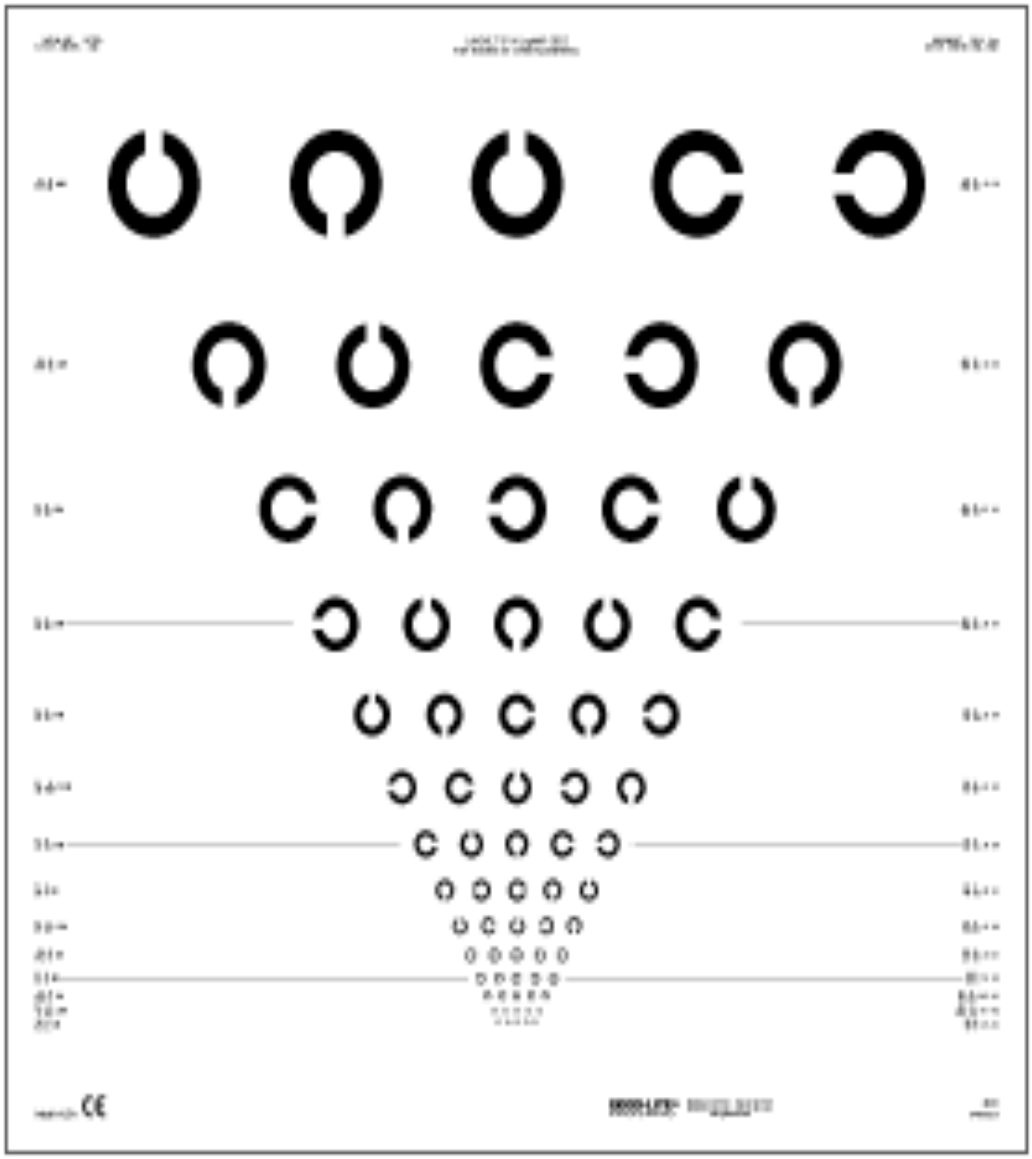
Line #: 12 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line #: 13 Guesses _____ _____ _____ _____ _____ ; #____/ 5

Line # 13 Guesses _____ _____ _____ _____ _____ ; #____/ 5

What computer testing is the subject performing today? _____ (e.g. A, G, H, K, M, W)

Appendix I: Landolt C Chart



Appendix J: Steps to run the "open door" program

Steps for running VISION 3 experiments: Series "a"

Once computer and monitor are on, and "acuity" experiment in Vision3.0 is highlighted:

1. depress "**Enter**" key on keyboard thereby entering the Acuity program

2. "Subject ID #": enter your **2 digit** ID# and hit the "**Enter**" key

3. "Special Designator": "**a**" "**Enter**"

4. "Name of Input File": "**0.txt**" "**Enter**" ; tutorial run with the lights on
   → "**1a.txt**" "**Enter**" ; This 1st expt COUNTS ... Lights out
   "**2a.txt**" "**Enter**" ; This 2nd expt COUNTS ... Lights out
   "**3a.txt**" "**Enter**" ; This 3rd expt COUNTS ... Lights out
   "**4a.txt**" "**Enter**" ; This 4th expt COUNTS ... Lights out

   (wait for a few seconds for the file to Load!)

5. "How many repetitions would you like?": "**1**" "**Enter**"

.....

Be sure you have one hand on JOYSTICK with the other on the left red button.

And that the lights are out and the door is closed. Get ready to respond!

6. "Hit "Enter" when you are ready to begin the experiment: "**Enter**"

.....

First time thru with experimenter you will do the "**0.txt**" "**Enter**" ; tutorial

After you run all four "**1a.txt**" , "**2a.txt**" , "**3a.txt**" , "**4a.txt**" expts, leave the room!

Appendix K: Post-Test Questions

Vision Experiments 10 Post-Test Questions Feb. 2015

Subject ID#: ___ Subject Name: _____ Today's Date: _____

1. Which expt series did you just complete? A? G? H? K? M? W? Other: _____

2. Was the expt: Way too long?__ Bit too long?__ About right?__ Bit too short?__

3. How clear were the directions provided (0-9)? ___ (0=totally unclear; 9=totally clear)

4. Did you experience any blurriness during the experiment? Yes / No

5. Did you experience any eye or vision discomfort during the experiment? Yes / No

6. If "Yes", what kind of discomfort did you experience? _____

7. How many hours today did you use a computer before doing this experiment? _____

8. Were those number of hours of computer use typical of your average day? Yes / No

9. Was there anything unusual or unexpected that you experienced? _____

_____

_____

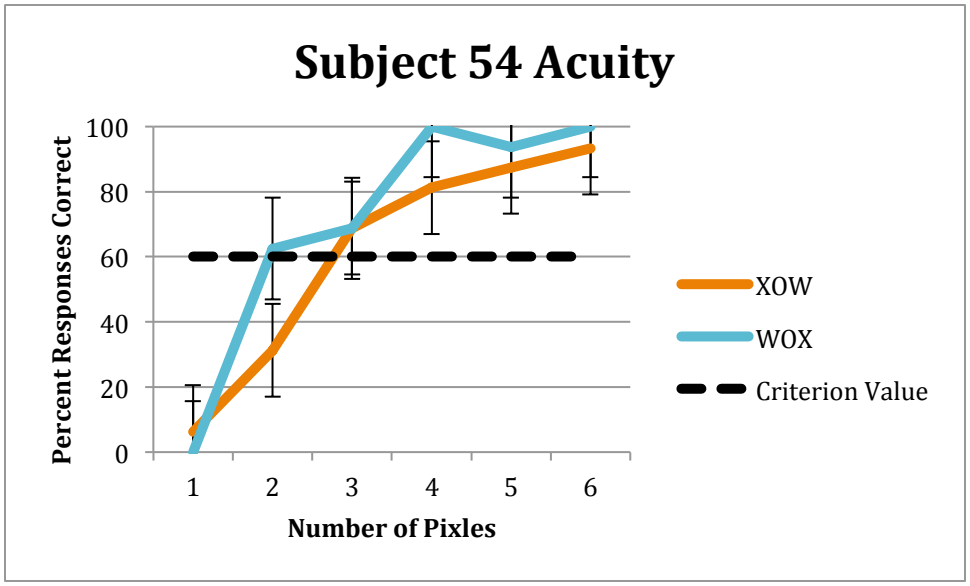
_____

_____

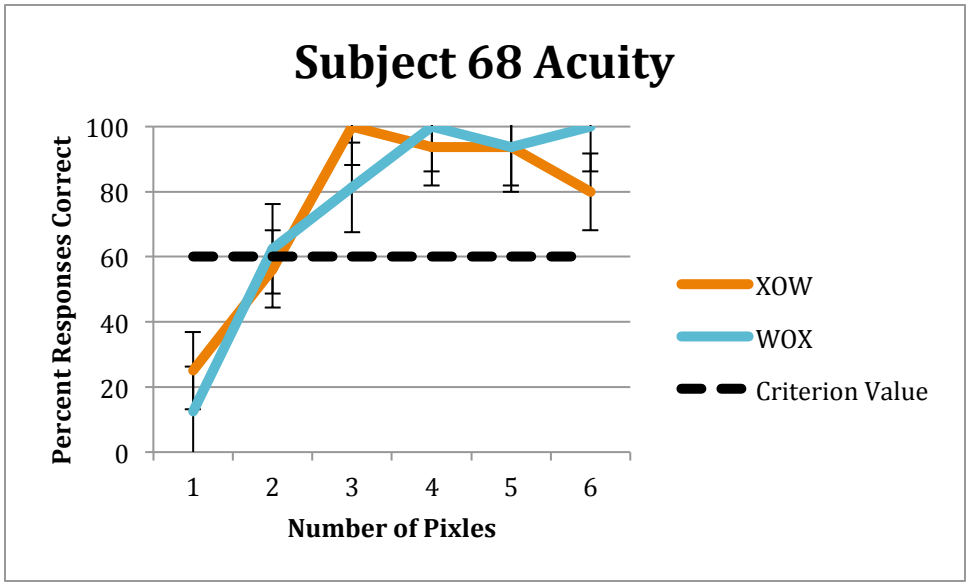
10. On a scale of 1-10, rate your experience: _____

Note: 1=Totally bored out of my mind; 5= OK as expected; 10=most fun I've had ever]

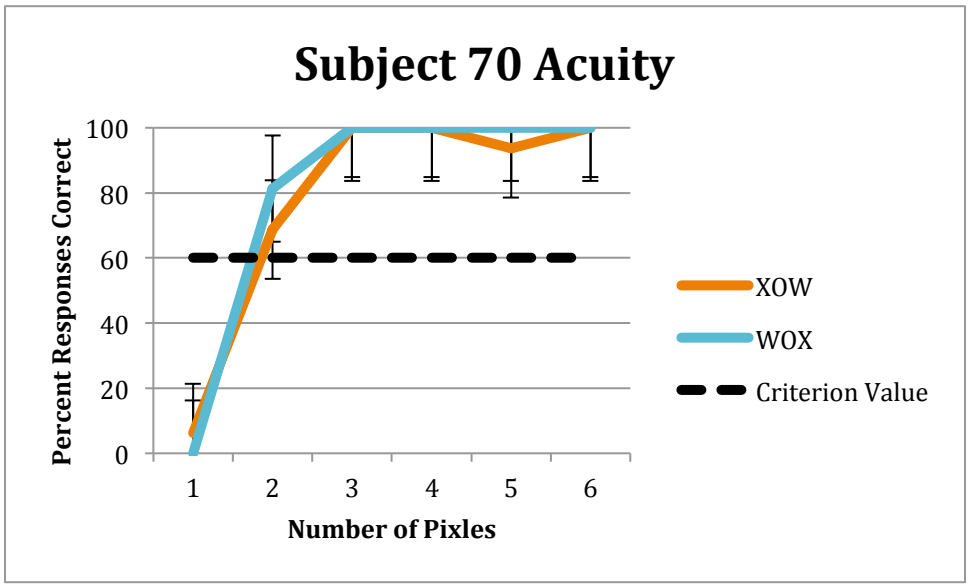
Appendix L : Visual Acuity Charts for subjects 68-155



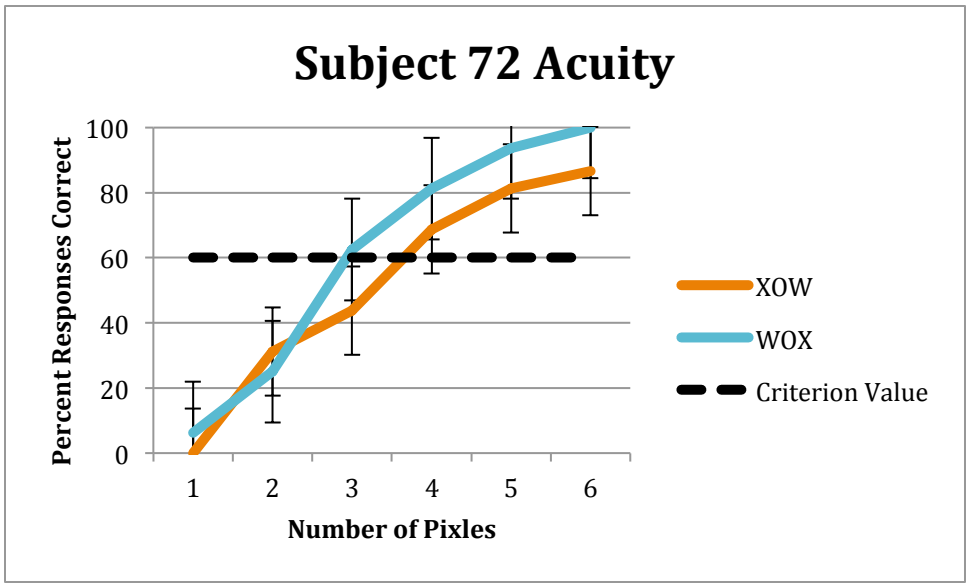
Graph 3.2 Subject 54 Acuity



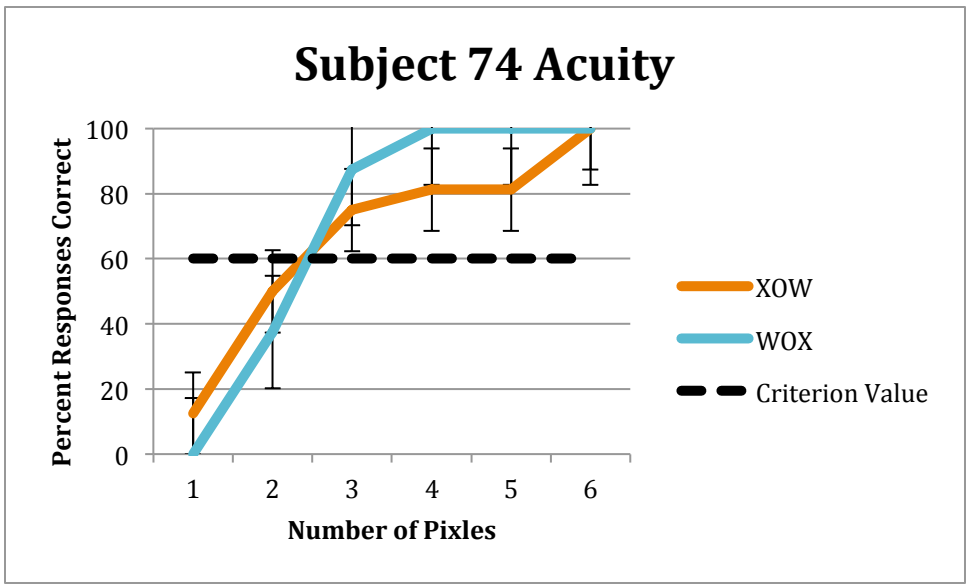
Graph 3.3 Subject 68 Acuity



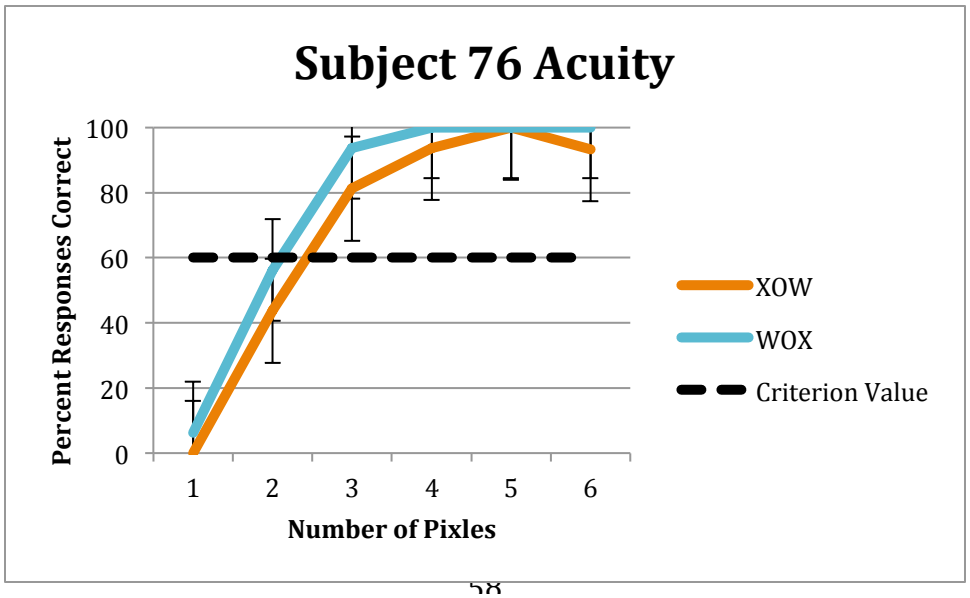
Graph 3.4 Subject 70 Acuity



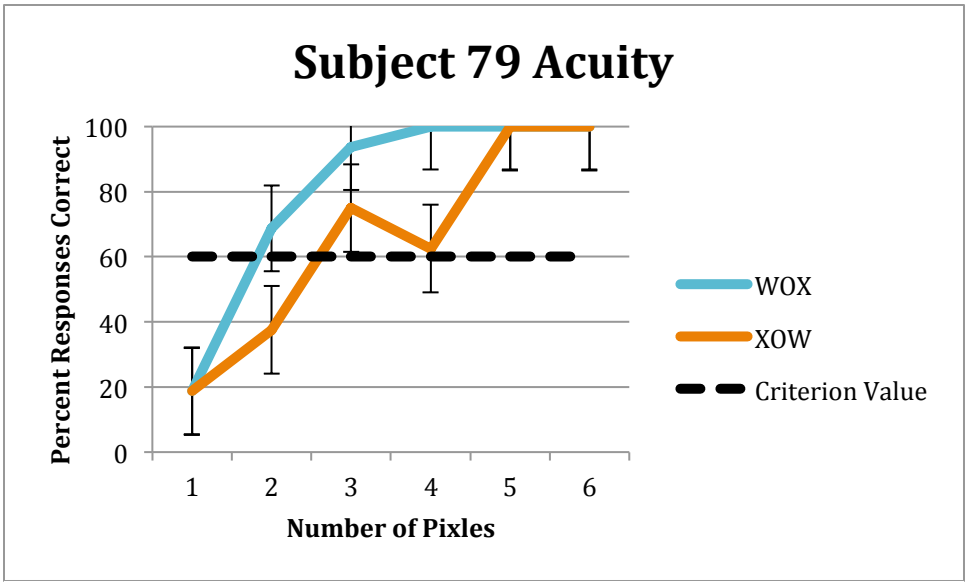
Graph 3.5 Subject 72 Acuity



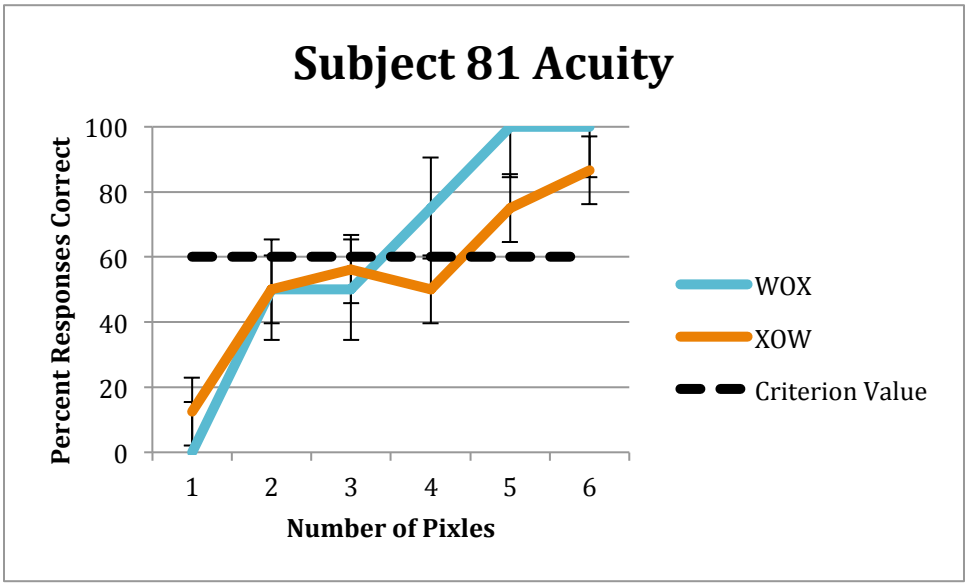
Graph 3.6 Subject 74 Acuity



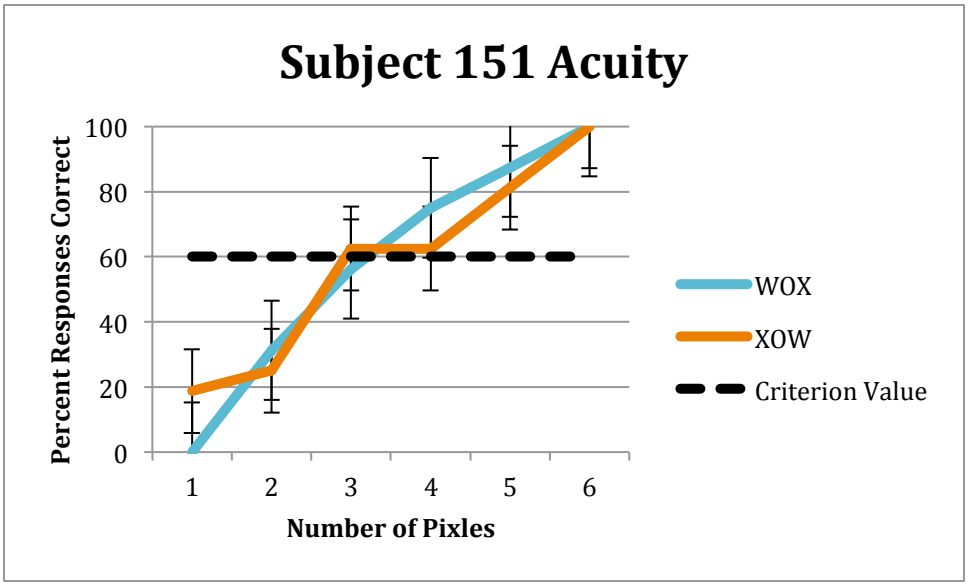
Graph 3.7 Subject 76 Acuity



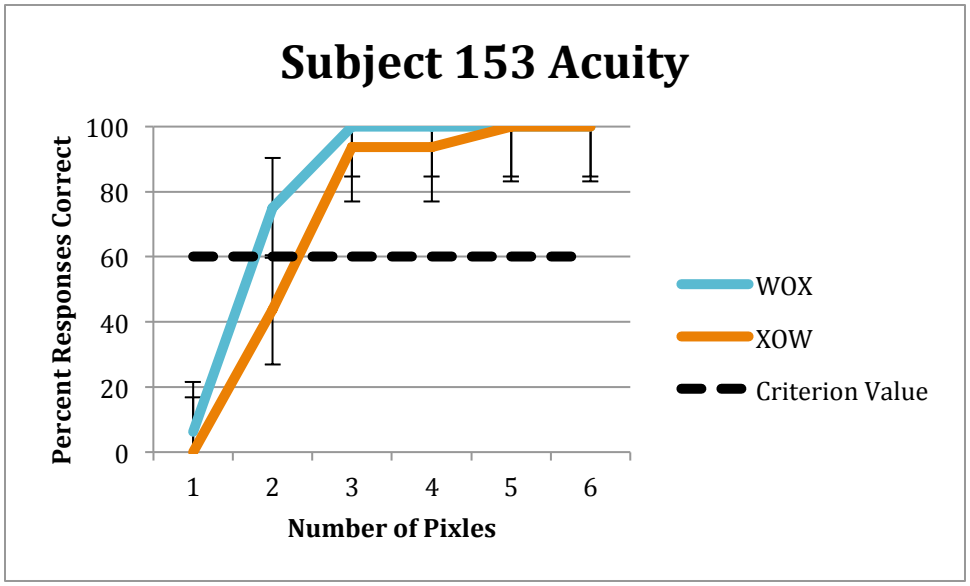
Graph 3.8 Subject 79 Acuity



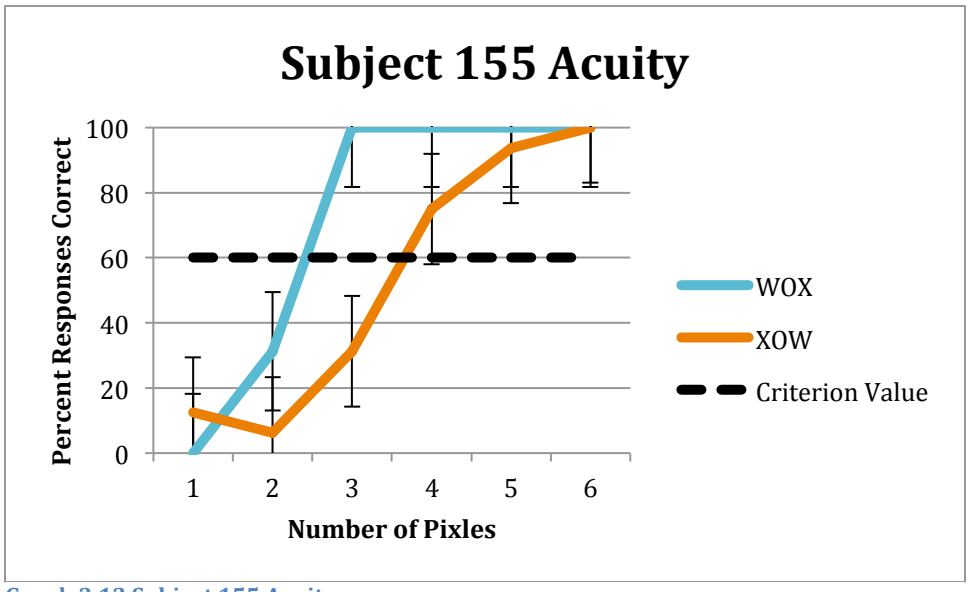
Graph 3.9 Subject 81 Acuity



Graph 3.10 Subject 151 Acuity



Graph 3.11 Subject 153 Acuity



Graph 3.12 Subject 155 Acuity

VII. Author's Biography

Ty Benjamin Bolte is a young whippersnapper with a knack for solving mysteries. Ty was born in Iowa, but spent much of his younger years moving around the United States. He graduated as valedictorian from Theodore Roosevelt high school in Des Moines, Iowa in 2011. He has been an EMT since 2013, and has most recently served as Assistant Chief at the University Volunteer Ambulance Corps (UVAC) in Orono, Maine.

After graduating from The University of Maine with a degree in Zoology (BS) he plans to work as an AEMT-Firefighter before enrolling in medical school in fall 2016. His future plans involve work in rural medicine and disaster management in developing countries. He is currently exploring medical school and residency options through the Navy with the Uniformed Services Medical School.