Extended Essay

Biology

Improvement in peripheral vision

Session: May 2018

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Can a simple computer program improve peripheral vision?

Abstract:

In this essay I shall respond to the research question:

Can a simple computer program improve peripheral vision?

I will investigate whether a simple 4-5 minute online computer program can be used to extend the edge of the peripheral vison of the participants. I will also investigate whether this computer program also improves focused peripheral vision.

There were 31 participants of different age groups: 21 participants in the experimental group and 10 in the control group. Their field of vision was measure in degrees using a vision disk. Black and white cards were used with two pairs of two different alphabets. Their far peripheral vison was tested on the degree mark when they could identify the presence of the card in their field of vison and their focused peripheral vision was tested on the degree mark when they could identify the letters on the card. In the experimental group the participants played the computer program before being tested again but participants in the control group waited for five minutes between being tested.

The results showed that the computer program did indeed increase both the field of vision and their near peripheral vison of the experimental group whereas the control group remained unchanged. The computer program was unfocused nevertheless increased the focused field of vision as they could read the letters on the cards at a wider angle than before they had played the computer program.

Words: 235

Why I chose this topic

I chose to test whether peripheral vison could be improved through a computer program as my brother is fond of playing games in which peripheral vision is crucial to success. While I have little interest in such games I am interested to know whether one can improve peripheral vision using a computer program. I have played such computer programs in the past, but was not convinced that they worked or not. An investigation for this essay gave me an opportunity to test the claim of these methods to improve the field of vision. I chose the vison disk as a method to measure peripheral vision due to several reasons. It was less time consuming than other methods and it used the least number of people e.g. using moving targets and gradually moving them in the field of vision. It was easy to use therefore I could perform a demonstrations for the participants on how to use it. I felt confident in using it as I could easily see the results. The method was non-invasive and followed the IBOs ethical guidelines. I chose the computer program from the website: brainHQ. As it was short and simple. It took approximately 4-5 minutes. Instinctively it seemed too short to be able to make a measurable difference to peripheral vison. Instinctively it seemed too short to be able to make a measurable difference to peripheral vision.

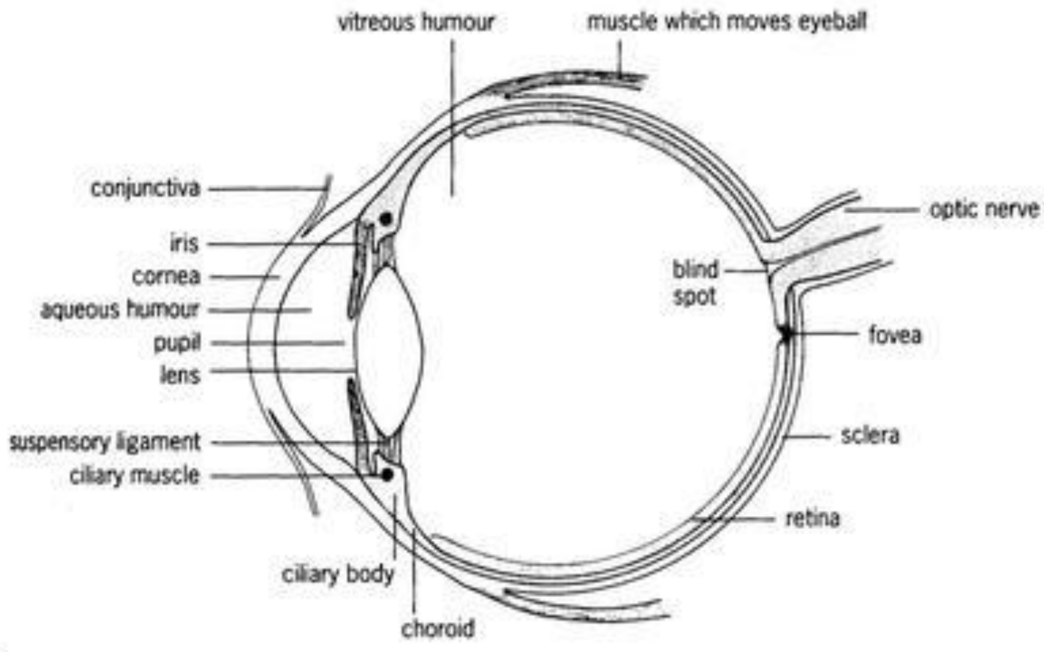

Figure 1: *horizontal section through the left eye.*

Background information

Peripheral vision is the side vision. It is the ability to detect objects and movements outside of the direct line of sight (Wikipedia 2018a) Vision occurs as a result of photoreceptor cells on the retina of the eye. Photoreceptor cells consist or rods and cones as well as photosensitive receptor ganglion cells. Rods are more sensitive than cones, however less sensitive to color. Peripheral vision is weaker in humans as compared to most animals (Wikipedia 2018a) due to the high concentration of the receptor and ganglion cells at the center and fewer at the edges of

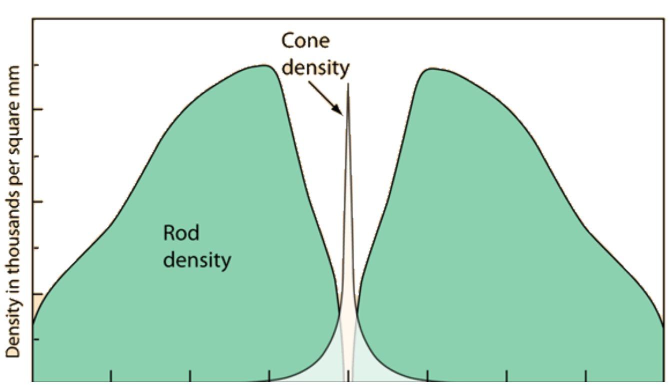

Figure 2 R*ods and cones following an inverse linear function (Nave,C.R), the edges of the retina that are responsible for peripheral vision have only rods.*

the retina in humans. Ganglion cells are specialized neurons that are on the inner surface of the retina (figure 1). Rod cells are concentrated at the edges (periphery) and the cones are concentrated at the center near the fovea (figure 2). The concentration of rods and cones in the eye can be explained by inverse linear function i.e. there are more cones in the fovea but fewer rods, similarly there are more rods in the periphery and fewer rods. Peripheral vision is important in detection of movement and has the ability to perceive flicker stimuli. (Karanovic *et al.,* 2011) .It becomes important when judging certain traffic situations and certain surroundings (MedicineNet 2018). The field of vision can be divided into 4 parts; the far peripheral vision, the mid peripheral vision, the near peripheral vision and the central vision.

An image is formed on the retina when light reaches the light sensitive inner lining of the retina through the cornea and the lens (figure 1). Hence light may be an important factor during the experiment. The photoreceptor cells in the retina (Figure 1) convert light into electrochemical signals which initiate the biological process i.e. they absorb the photons and which trigger the change in the membrane potential of the cell. These signals pass through the interneurons in the second layer which contains bipolar cells to the ganglion cells in the third layer. Ganglion cells organize these signals and send them to the brain via the optic nerve (figure 1). The lateral geniculate nucleus in the thalamus separates the input from the retina into equivalent streams, one with fine structure and color and the other with motion and contrast. (Wikipedia 2018b).

Cones are responsible for detecting color and rods are responsible for detecting shapes and

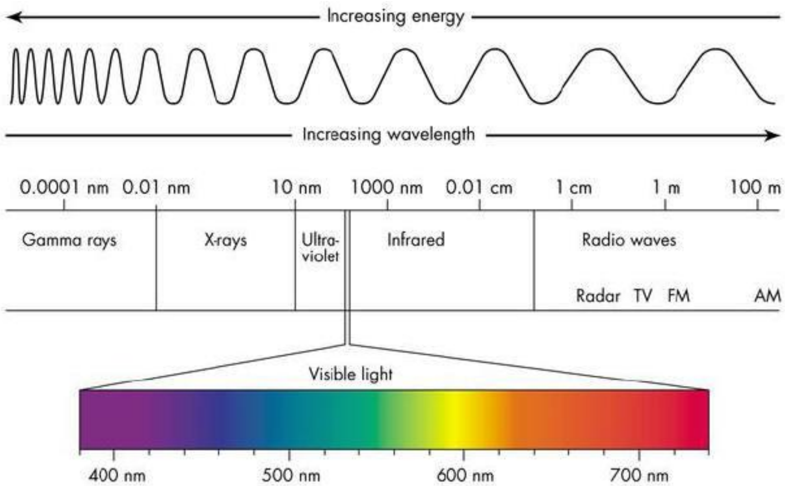

Figure 3 *visible light spectrum*

movement. There are three type of cones L-cones, S- cones and M-cones, each of them is responsible for perceiving red (long wavelengths), blue (short wavelengths) and green (medium wavelengths) respectively as seen in figure 3. Although the experiment does not investigate the density of the cones, an experiment can be conducted using colored cards to study the density of the cones in the near and far peripheral vison. However in some of my participants I observed color deception as they reported seeing different colors in their far peripheral vision but the correct color in their near peripheral vision. Color deception is when adjacent colors on the color wheel lead to misinterpretations [Quizlet, 2018]. This could be due to the amount of cones present in the periphery. Rod cells are longer than cones. They are more sensitive and can function in less intense light than the cones. They play a big role in night vision, however less role in color vision. (Wikipedia 2018c)

The retina consists of three neuron layers. The first layer has cones and rods which send signals to the middle layer of inter neurons which relay the message to the third neuron layer containing ganglion cells. The image at the fovea is clear due to the fact that the ganglion cells near the fovea receive signals from a few cones and rods allowing it to make a detailed image. In contrast peripheral images are a blur and as one ganglion cell receives signals from many

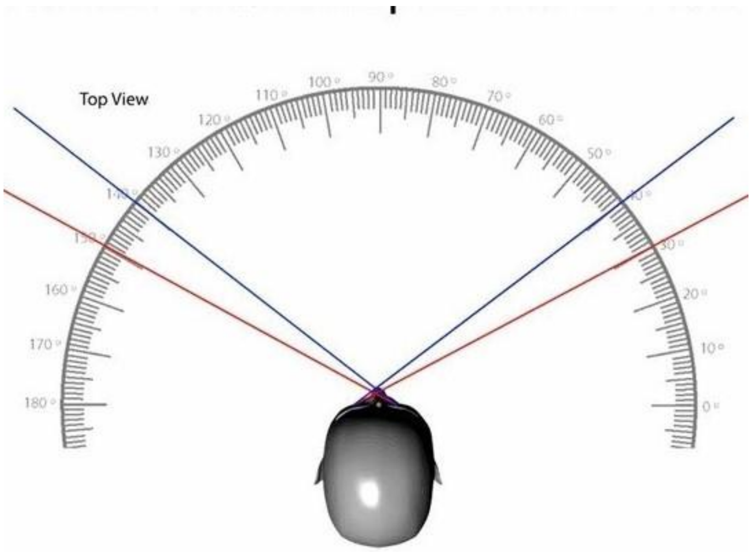

Figure 4 *illustration of peripheral vision*

rods and cones which explain the lack of detail. Information from the periphery has to be compressed before its transmission to the brain, this causes an overflow of information to one ganglion cell which can be used to explain the blurriness of peripheral vision. (Johnson, 2010)The color perception and sharpness of an image is better in the fovea than in the periphery. There are roughly 6 million cones and about 120 million rods in the human retina. Color deception can be observed which correlates to the distance from the fovea.

Covert attention is the distribution of attention to targets or locations away from the point of fixation in the visual field, without the movement of the eyes. Whereas overt attention is direct attention to targets/locations at the point of fixation with the movement of the eyes. According to previous research perceptual training in peripheral vision with letter recognition tasks can result in faster reading speed and letter recognition (Chung, Legge, & Cheung, 2004) an experiment conducted by Chung *et al.* (2004) indicated that perceptual training resulted in an increase in reading speed and visual span in peripheral vision. There is a possibility that the changes in perceptual vision detected by Chung *et al* (2004) were due to improved use of covert attention. The training of peripheral vision may improve the ability of the participants to distribute attention from the point of fixation to targets/locations in peripheral vision. There is evidence to suggest that pre cueing the peripheral target/location might enhance performance in several visual tasks (Posner, 1980; Shiu & Pashler, 1995; Davis, Kramer, & Graham, 1983; Yeshurun & Carrasco, 1998, 1999). Pre cueing of targets might allow the participants to expect the target at the location. The pre cuing of targets in the peripheral vision allows for attention to be allotted in advance to the prompted location, hence improving the processing of any object or target that appears in that location. The control experiment was conducted to test whether pre cuing would extend the field of vison of the participants, without the computer program if they were expecting a target in their peripheral vision. A major factor that limits the size of the field of vision is crowding, the intrusion of adjacent letters, which is more distinct in peripheral vision. It was shown by Lee, Legge, and Ortiz (2003) that higher level language processing is similar for inputs from central vision and peripheral vision, suggesting that there is no extra linguistic exertion in reading in peripheral vision.

Lee, Legge, and Ortiz (2003) further showed that higher-level language processing is similar for inputs to central and peripheral vision, implying no extra linguistic difficulty in reading in peripheral vision. Hence the task of recognizing the letters in the experiment should not come as a difficulty to the participants.

Age plays an important role in the effectiveness of vision. It is estimated that our field of vision decreases by one to three degrees every decade of our life (allaboutvision). Aging cause a loss of neurons and therefore vision in the eye. Aging also decreases the density of photoreceptors hence narrowing the field of vision according to a study conducted in the ophthalmology department at university of Erlangen Nuremberg (Ncbi).   The matter of how efficiently people can divert their attention to a non-foveal retinal location is related to the development of a favored retinal locus in people with age related macular degeneration. According to a study conducted by Panda Jonas *et al. (1995)* photoreceptor density decreased with increasing age, outside the foveal center. This study was not specifically designed to see the effect of aging, but this variable will be kept in mind when looking at the data.

Design

Hypothesis

Playing the computer program will extend the range of the participants' far peripheral vison.

Research question:

Can a simple computer program extend the limit of the participants' far peripheral vision?

The independent variable (IV)

The change in the edge of peripheral vison of the participants.

The dependent variable. (DV)

The limit of the far peripheral vison of the participants before and after the computer program.

A vision disk is a device used to measure the field of vision and is calibrated in degrees; it can be placed on the bridge of the nose directly on the level of the eye or on the forehead. For this experiment, the vision disk was placed on the bridge of the nose for each participant.

Participants:

The experiment was performed on a sample of a total of 31 international participants. Their ages ranged from 17 to 62. They were randomly divided into 2 groups, experimental and control. The control group consisted of 10 participants and the experimental group comprised of 21 participants. Each participant was requested to sign a consent form (refer to appendix A) before the experiment and debriefed at the end of the procedure. Their right to confidentiality and the right to withdraw was maintained. The peripheral vision of the participants was measured twice during the course of the experiment.

Experimental method

The participants were asked to keep vision disk on the bridge of the nose at eye level. The participants were asked to focus on a pencil placed directly at the 90 degree mark on the vision disk. They were requested to focus straight and not to move to the side. The cards were black and white with two pairs of 2 different letters of the alphabet. Cards were placed on the vision disk beyond the participant's line of sight and moved gradually into their field of vision. The participants were requested to say when they could first see the card at the edge of their peripheral vison and when they could correctly read the letters written on the cards. This was carried out for both sides/eyes. The measurement in degrees on the vision disk were noted when the participant reported to see changes in the card they were then asked to play the computer program which claims to improve visual precision. A computer program was chosen as a method to improve peripheral vision due to easy availability and time constraints. The computer program is called Hawkeye from the website brainhq.com. The game comprised of several stages. The participants were exposed to a scene of birds with a blue background, one of those birds was different from the rest. The participants were only exposed to the scene for very short periods of time after which they had to point out by clicking on the different bird. With each stage the amount of time the scene was exposed was shortened.

The degrees at which the participants could first see the card and then read the letters on the card were noted. The point at which the participants could first see the card was recorded as "Field of vision (FV)" and the point at which they could read the letters on the card was recorded as "read full card". The first time their peripheral vision as measured was called initial and the second time it was measured was named final. The right and left side measurements were added together and this total, in degrees, which represents the maximum edge of the field of vison was plotted on the graphs.

After the program their peripheral vision was measured again using the same method. The cards were changed each time and the participants were not shown the card before the experiment. The data was recorded in degrees. The experiment took about 20 to 25 minutes for each participant.

Control method

The procedure was same as the experimental method except the participants were not asked to play the computer program. Their peripheral vision was measured twice with an interval of about 5 minutes in between.

Results:

The results are represented in the form of tables in Figures 5,6,8 and 9 and plotted on the graphs in Figures 7 and 10 .The y=x lines were included in both graphs as a normal for a comparison of the findings to observe how much difference the procedures made. The results for the control reading almost sit on the x=y line which shows no/minimal difference in the measurements without the computer program. From the graphs it can be deduced that there was a general increase in the edge of peripheral vision of the participants as almost all the data sits above the x=y line. In Figure 10 the data is congested in one areas of the graph unlike in Figure 10 where the data is more spread out. The regression line of the experimental data in Figure 7 makes an intersection with the x=y line, this will be further explained in the discussion. The data in the tables are a total of the right and left side of the readings (in degrees) on the vision disk as reported by the participants.

participant	initial FV (degrees)	final FV (degrees)
1	180	183
2	174	185
3	186	189
4	159	172
5	155	172
6	190	201
7	181	188

8	159	187
9	180	195
10	168	170
11	191	200
12	158	180
13	189	189
14	187	197
15	172	187
16	187	170
17	177	182
18	187	201
19	204	200
20	169	182
21	144	176

Figure 5: *The initial and final readings for the field of vison (FV) before and after having done the computer program.*

Participant	Control FV initial (degrees)	Control FV Final (degrees)
1	173	174
2	160	164
3	183	185
4	200	198
5	164	165
6	195	197
7	170	168
8	177	178
9	161	164
10	178	177

Figure 6: *the initial and final readings for the field of vision (FV) of the control group, just having waited 5 minutes before taking the reading.*

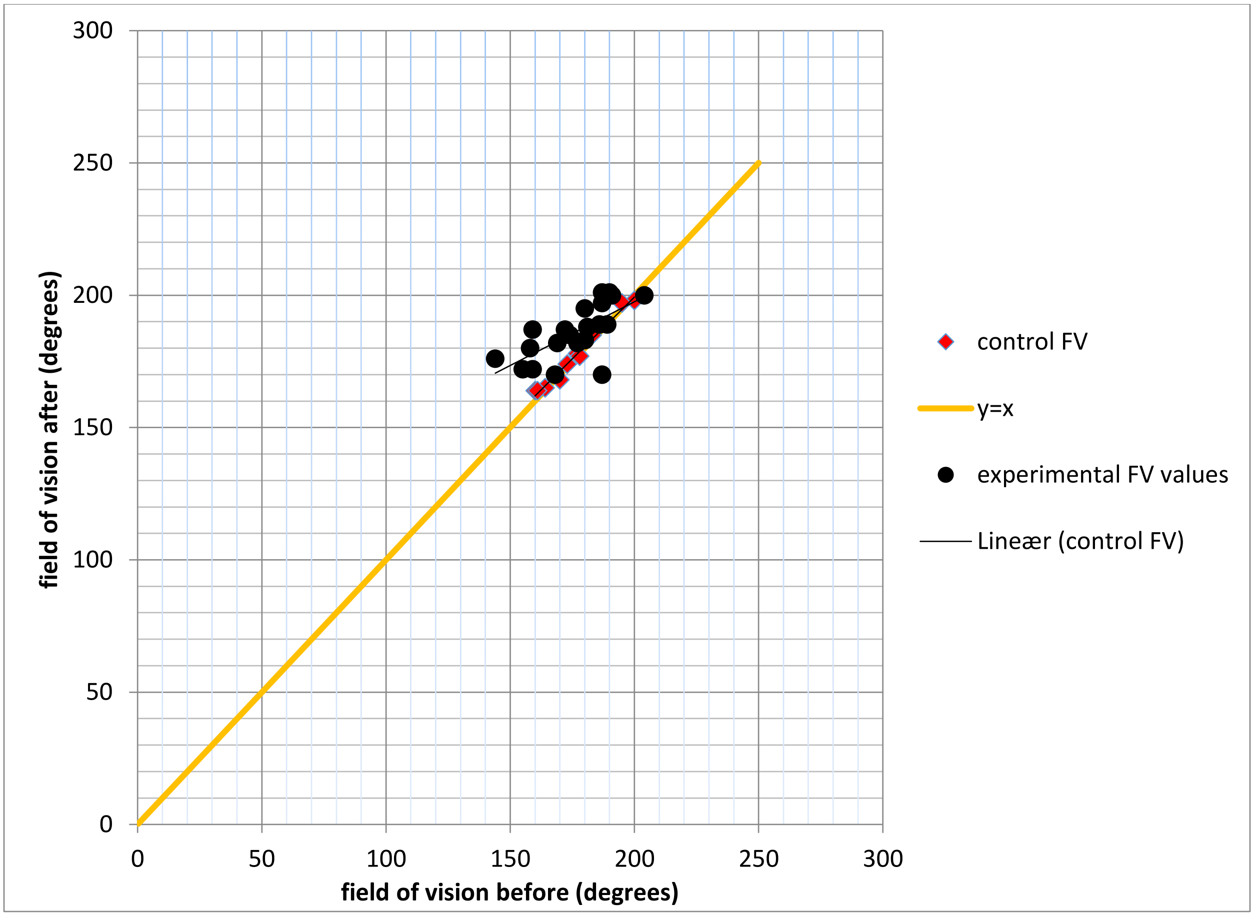

Figure 7 *graphical representation of the experimental values and control, data from figures 5 and 6.*

participant	Read full card initial (degrees)	Read full card final (degrees)
1	29	40

2	22	37
3	38	42
4	40	69
5	21	37
6	36	39
7	30	37
8	69	86
9	17	23
10	48	52
11	81	107
12	19	22
13	40	50
14	34	38
15	27	39
16	12	29
17	24	35
18	22	61
19	28	48
20	29	42
21	22	23

Figure 8: *the initial and final readings for when the participants could reading the letters on the card before and after having done the computer program.*

Participant	Control read full card initial (degrees)	Control read full card final (degrees)
1	31	30
2	52	55
3	50	50
4	70	66
5	29	31
6	37	33
7	28	31
8	49	44
9	24	24
10	43	45

Figure 9: *the initial and final readings for when the participants could read the letters on the card for the control group having waited 5 minutes before taking the reading .*

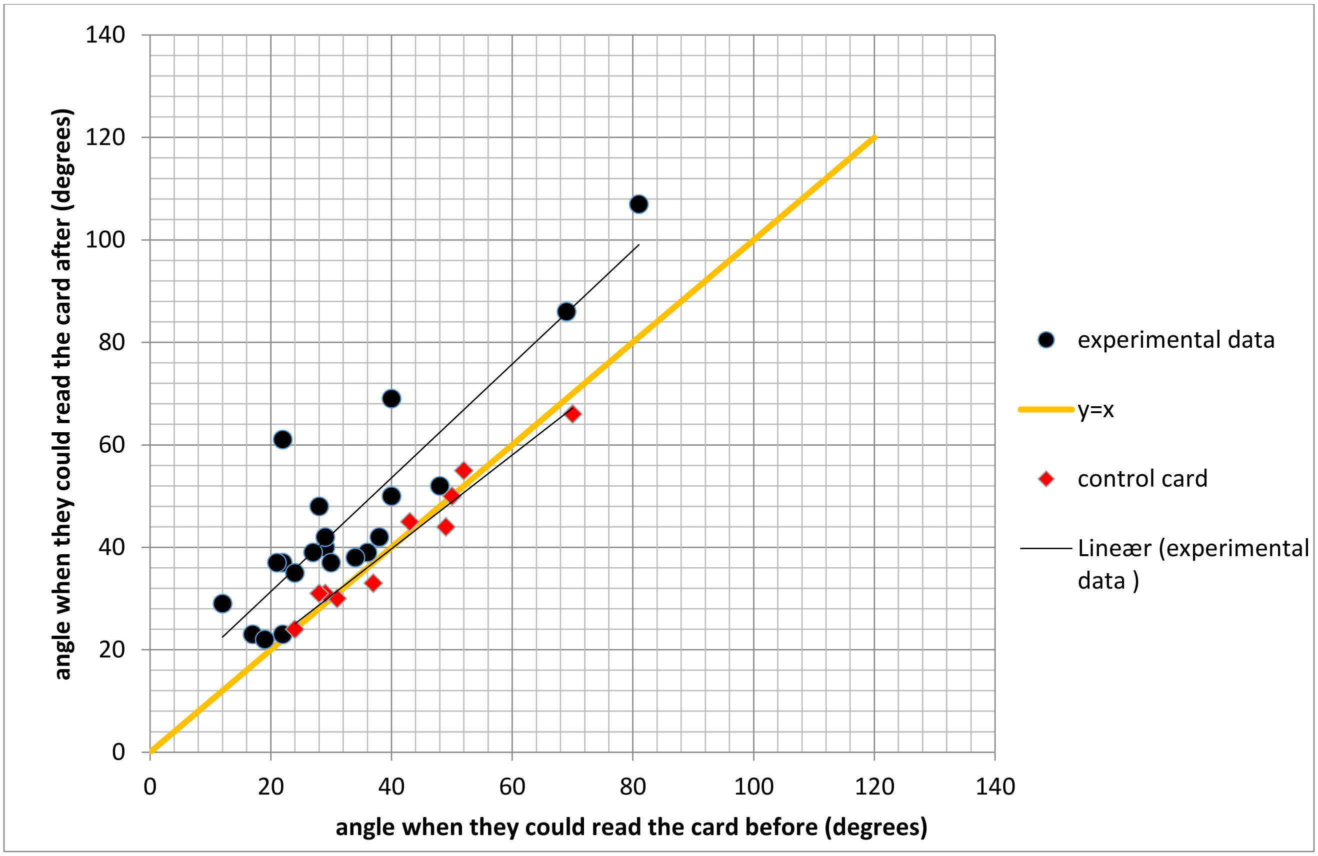

Figure 10: *when the participants could read the letters on the card, control and experimental.*

Discussion:

There is always a possibility that the participants would do better the second time they have their peripheral vision tested, simply because they are more familiar with what to expect. The function of the control experiment is to examine this possibility. If there is no difference between the two tests then the results will fall directly on the x=y line. It is remarkable to see how close the control experiment matches this line both when measuring the limit of the far peripheral vision (Figure 10) and the limit of the resolution of the near peripheral vision.

The control values in both graphs lie very closely on the x=y line. The control experiments show minute changes which indicates that the computer program effected the peripheral vision.

The equation for the regression line of the control experiment is:

$$y = 0.9338x + 12.555$$

The gradient of the line is 0.9338 which is very close the gradient of the x=y line which demonstrates that the control experiment almost made no/minimal difference in the far peripheral vision.

The equation of the regression line for the control experiment in Figure 10 is:

$$y = 0.9153x + 3.0972$$

The gradient of this line is 0.9153 which is also very close to the gradient of the x=y line. It shows that the experiment made no/minimal difference in the near peripheral vision.

The results for the field of vision (Figure 7) show that the computer program leads to an extension of the edge of peripheral vison of the participants as almost all the results are above the x=y line which is important. In figure 7 it can be observed that the measurements are generally crowded in an areas on the graph but on figure 10 the measurement tend to be more spread out. In figure 7 the trend line is converging towards the x=y line. One experimental value in Figure 7 is below the x=y line which shows that the particular participant did not improve after the computer program, this could be assumed as an anomaly or an unexpected value. The trend line in figure 10 is converging away from the x=y line. The data will eventually reach a limit after which no more improvement in the peripheral vision can be observed this can be explained by the intersection of x=y line and the regression line of the experimental data in Figure 7.

The equation of the experimental data regression line in Figure 7 is:

$y = 0.4819x + 101$

The gradient for this slope is 0.4819 which shows a significant difference between the slope of this line and the x=y line. The gradient of the line also shows that the computer program did not improve the peripheral vision evenly for every participant. To find the intersection between the two lines, simultaneous linear equations can be used

$y =$ 0.4819x+101

$y = x$

By solving this,

$x = \frac{1010000}{5181}$

$y = \frac{1010000}{5181}$

These points on the graph represent the limit of the far peripheral vision after which it is physically impossible to improve and the computer program would make no further difference.

The equation of the regression line of the experimental data in Figure 10 is:

$y = 1.1101x + 9.1555$

This equation, however may be less reliable as the points are scattered .The gradient of this line is 1.1101 which is close to 1.00 which is the gradient of the x=y line. Therefore these lines are not far from being parallel.

The computer program was unfocused peripheral vision training but it can be seen to improve unfocused and focused peripheral vision for most of the participants. Control and experimental readings for the field of vision are packed almost in the same area. But control and experimental values for the participants reading the card are more spread out. This supports the idea that we are better at detection inside our field of vision but worse at distinguishing shape, size and color. The results support the hypothesis that a there was a change in the peripheral vison. Overall the graphs show an improvement in the peripheral vision before and after the computer program. According to the study by Panda Jonas *et al. (1995)* a narrow field of vision can be expected in older participants. However there is not enough data for this pattern to be studied/observed due to the small sample size.

I find it extraordinary that such a short and simple computer program can result in a measurable improvement in a participant's peripheral vision. It would be interesting to know for how long this improvement continues. This improvement in peripheral vision can benefit drivers of who can drive safer, and help them in assessing certain traffic situations. People who play computer games that rely on peripheral vison might score higher. Improved peripheral vision could also help in sports where there is a need to see the entire field e.g. baseball etc. In animals improvement in peripheral vision could allow them to spot their predators in their peripheral vison at a farther angle from the center of gaze.

Observations:

At larger angles the participants reported to see the card only when it was being moved. This could be explained by the vibrations of the cones and rods to make an image. The still card did not make any movements and therefore could not be registered on the rods and cones. Most of the participants claimed to see the word father from the center before seeing the word closer to the center (90 degree mark on the vision disk). They had difficulty focusing on the pencil at the 90 degree mark and were very tempted to look directly at the card.

I noticed that there was a difference in the peripheral vision on of the left and right side of the participants. The participants seemed to perceive different letters and colors than the original as the card came closer. Which can be explained by the theory that peripheral vision is bad at detecting color, size and shape. There was a general increase the field of vision for almost all the participants.

Limitations:

Some of the participants did not keep the vision disk directly on their nose therefore the readings show more than 180 degrees on the vision disk. The sample size was too small to make observations about gender or age. It can be argued that the procedure and the equipment employed in the experiment were not very sophisticated and accurate. Slight changes in the lighting might have affected the results. The participants experience with computer programs might have an effect on the results. The sizes of the screen used to play the computer program varied, therefore this might also affect the accuracy of the results.

Participants with very poor eyesight had to wear spectacles during the experiment, which did not allow the vision disk to sit between the bridges of their noses and therefore some of the readings are more than a total of 180 degrees. A follow up experiment could not be conducted and therefore the effects of the computer program are assumed to be temporary. There are different methods that could be applied to estimate the field of vision more accurately, however due to time constraints and limited resources they could be employed.

Improvements:

The experiment can be conducted on a wider range of participants, for example a wider age range and more participants. The experiment can be conducted to study the effects of the computer program in extending the edge of peripheral vision in on a different ages or genders. The experiment can be carried out with more sophisticated equipment for more accurate results. A more control environment should be used to eliminate confounding variables due to lightning changes or changes due to screen size. Participants with poor eyesight should be requested to wear contact lenses as not to contaminate the results. A follow up experiment could be conducted to examine the 'long term' effect of the computer program. There should be strict control over the movement of the eyes of the participants so that they do not look directly at the card and hence contaminating the results. An experiment using colored cards could be used to study the accuracy of the cones which detect color. If anomalies e.g. in figure 7 would be investigated in detail a larger sample size and more sophisticated equipment should be used for accurate results.

Conclusion

Conclusively, the results did improve the field of vision of the participants. The finding were significant as they show that training the peripheral vison with as little as a 5 minute computer program can widen the angle of peripheral vision. There was a general increase in the participant's field of vison and their ability to identify the letters on the card at a wider angle than before the computer program. To answer the research question, yes a simple computer program can improve peripheral vison.

Appendix A

Informed Consent Form

Name of researcher: ...

The following will provide you with information about the experiment that will help you to decide if you wish to participate. First of all your peripheral vision will be measured using a vison disk. The researcher will demonstrate how it works. Then you will be asked to play a short game that claims to enhance peripheral vison, Afterwards your peripheral vison will be measured again using the same method as before. You are asked your age in this form as the experiment will also compare the results with different age groups. All the information you provide will remain confidential and will not be linked with your name in the research and the findings. Your participation is voluntary, and you may withdraw at any time during or after the experiment. The researcher will debrief you after the experiment has concluded. There is no risk linked to this experiment and it follow the IBO's ethical guideline. If you wear glasses please state your vision number (for example 20/20 vision etc.).

___________ Vision.

By signing below, I confirm that I approve to be a participant in this study, allowing my results to be used in the report. I have read and understood the information in this form given by the experimenter. If you have any further questions feel free to ask the researcher.

Name of Participant: ____________________________________

Age: _____________

References:

Allaboutvision.com.2017. *How Your Vison Changes As You Age.* [ONLINE]. Available at: http://www.allaboutvision.com/over60/vision-changes.htm. [Accessed 2 February 2018].

Chung, S.T., Legge, G.E., Cheung, S.H. 2004. *Letter-recognition and reading speed in peripheral vision benefit from perceptual learning.* [ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pubmed/14751554 [Accessed 10 October 2017]

brainHQ.2017. *Hawk Eye. [ONLINE]. Available at:* https://www.brainhq.com/why-brainhq/about-the-brainhq-exercises/brainspeed/hawk-eye. *[Accessed 25 December 2017].*

Hye-Won Lee; MiYoung Kwon; Gordon E. Legge; Joshua J. Gefroh. 2010. Training Improves reading speed in peripheral vision: Is it due to attention? [ONLINE] Available at: http://legge.psych.umn.edu/sites/g/files/pua2126/f/lee1.pdf [Accessed 2 January 2018].

Interaction Design Foundation. 2018. Vision and Visual Perception Challenges. [ONLINE]. Available at: https://www.interaction-design.org/literature/article/vision-and-visual-perception-challenges

[Accessed 21 October 2017]

Lachenmayr, B. 2006. *Visual field and road traffic. How does peripheral vision function?*

[ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pubmed/16328491 [Accessed 7 December 2017]

Lee, H.-W., Kwon, M., Legge, G. E., & Gefroh, J. J. 2010. Training improves reading speed in peripheral vision: Is it due to attention? *Journal of Vision*, **10**(6): 18, 1–15, [ONLINE] Available at: http://legge.psych.umn.edu/sites/g/files/pua2126/f/lee1.pdf

MedicineNet. 2018. Medical Definition of Peripheral vision. [ONLINE]. Available at: https://www.medicinenet.com/script/main/art.asp?articlekey=10638 [Accessed 1 February 2018].

Nave, C. R. 2016. *The Rods and Cones of the Human Eye.* [ONLINE] Available at: http://hyperphysics.phy-astr.gsu.edu/hbase/vision/rodcone.html [Accessed 5 November 2017].

Karanovic, O, M. Thabet, H.R. Wilson & F. Wilkinson.2011. Detection and discrimination of flicker contrast in migraine. *Cephalalgia* **31**(6):723-736 [ONLINE]. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3571449/

Ncib.2011. Detection and discrimination of flicker contrast in migraine. [ONLINE]. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3571449/. [Accessed 9 January 2018].

Panda-Jonas, Jonas JB, Jakobczyk-Zmija M. 1995. Retinal photoreceptor density decreases with age. [ONLINE]. Available at: https://www.ncbi.nlm.nih.gov/pubmed/9098287. [Accessed 1 February 2018].

Johnson, J. 2010. Designing with the Mind in Mind: Simple Guide to Understanding User Interface Design Rules. Ch. 6: Our Peripheral Vision is Poor Morgan Kaufmann, San Francisco, CA.

Personal.umich.edu.2010. *Our Peripheral Vision is Poor.* [ONLINE]. Available at: http://www-personal.umich.edu/~itm/688/wk8%20%20Psychology%20and%20Design/designing%20with%20the%20mind%20in%20mind/science-05.pdf.

Quizlet. 2018. *1.4* [ONLINE] Available at: https://quizlet.com/120718146/14-flash-cards/ [Accessed 13 December 2017]

Science Buddies. 2016. *Put Your Peripheral Vision to the Test.* [ONLINE]. Available at: https://www.scientificamerican.com/article/put-your-peripheral-vision-to-the-test/ [Accessed 14 January 2018]

Science Buddies. 2017. *Now You See It, Now You Don't! Test Your Peripheral Vision*. [ONLINE]. Available at: https://www.sciencebuddies.org/science-fair-projects/project-ideas/HumBio_p016/human-biology-health/test-your-peripheral-vision#summary. [Accessed 14 January 2018]

Wikipedia. 2018. *Peripheral vision*. [ONLINE] Available at:

https://en.wikipedia.org/wiki/Peripheral_vision [Accessed 14 January 2018].

Wikipedia.2018. Lateral geniculate nucleus. [ONLINE]. Available at:

https://en.wikipedia.org/wiki/Lateral_geniculate_nucleus [Accessed 2 January 2018]

Wikipedia.2018. *Rod cell.* [ONLINE]. Available at:

https://en.wikipedia.org/wiki/Rod_cell [Accessed 2 January 2018]

Science Blogs.2012*. How many colors are really in a rainbow?* [ONLINE]. Available at:

http://scienceblogs.com/startswithabang/2012/08/14/how-many-colors-are-really-in-a-rainbow/ [Accessed 21 October 2017]