

# A Novel and Low-Cost Visual Aid for Retinitis Pigmentosa Patients to Improve Peripheral Vision Loss

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## ABSTRACT

Retinitis pigmentosa (RP) is a genetic eye disorder that affects 1 in 3000-8000 people worldwide and causes the deterioration of the light sensitive pigmented layer of the eye. Typical symptoms include night blindness and subsequently decreasing visual fields. Unfortunately, the specific cause of RP is not known and there is no cure. The disease is currently managed by expensive visual aids ranging from \$3000 to \$6000. This creates a need to develop affordable glasses for the common individual. In this study, 3D printed glasses were developed that enhanced the peripheral vision of the mocking RP patient (student researcher) utilizing external smartphone wide-angle lenses. To test different levels of tunnel vision, 3D printed circular discs with hole sizes of 1 mm, 3 mm, 5 mm, 7 mm, and 9 mm were created representing the varying severity of vision loss in RP patients. These discs were inserted in the frames of 3D printed glasses with and without wide-angle lenses. The student researcher validated these glasses on a bullseye model and observed a doubling in the visual field. Three replication data was collected comparing normal vision and different levels of RP (using tunnel vision discs) with and without the wide-angle lens glasses. Regression analysis of data generated from a Monte Carlo Simulation and T-Test procedure further confirmed a statistically significant increase in the visual field utilizing wide-angle lens glasses. Thus, a cost-effective visual aid (\$20) was developed by the student researcher to improve peripheral vision and break socio-economic barriers for RP patients.

## **Introduction**

Retinitis pigmentosa (RP) is a rare eye disease resulting from probable genetic variations that are passed on through inheritance, affecting 1 in 3000-8000 individuals worldwide (Hamel, 2006; Hartong et al., 2006). Occurring in syndromic (with Usher syndrome and Bardet-Biedl syndrome) and non-syndromic nature, Retinitis Pigmentosa leads to the progressive vision loss caused by the gradual degeneration of light-sensing rod cells of the retina behind the eye. Unfortunately, the specific cause of RP is not known, and currently there is no cure. More than 58 genes have been reported to be associated with RP, and most of these genes are either expressed in photoreceptors or the retinal pigment epithelium. Lowered night vision and decreased peripheral vision (high tunnel vision) are some of the earliest symptoms of RP, and photoreceptor rods appear to be more affected than cones (Ali et al., 2017). A study conducted by Eli Peli, a professor of Ophthalmology at Harvard Medical School and a vision scientist at the Schepens Eye Research Institute of Massachusetts Eye and Ear, concluded that “the risk of collision is highest from pedestrians at an angle of 45 degrees from the patient's walking path” (Peli et al., 2007; 2016). A road safety observatory reported that 2% to 3% of drivers who were involved in car accidents had vision below the minimum legal standard (Rubin et al., 2007). Indeed, RP patients coming at 45 degrees from their walking path are known to encounter accidents with cars or other vehicles leading to serious consequences.

Affordable visual aid glasses with wide-angle lenses that mimic human peripheral vision will help patients carry out daily tasks and help break socio-economic barriers due to its affordability. Since the price will be low, anyone without vision insurance should be able to afford these visual aids. This device can revolutionize the branch of optics and may become more globally accessible through mass production. Through the development of this visual aid, the common difficulties of individuals with impaired vision will be lessened to such a significant degree that common independent tasks like driving and walking may become a reality. Thus, this device will reduce the visual gap between impaired and unimpaired individuals.

Most projects in the field of optics are developing visual aids that improve the users' experience with a variety of features such as magnification, viewing live scenes from the surroundings, recognizing faces, and limited peripheral vision. However, these projects fail to develop affordable glasses for the average individual. Therefore, the main goal in this project was to develop affordable glasses that could enhance the peripheral vision of the patient through common wide-angle lenses. Although a few peripheral vision aid devices have been released into the market in the past few years, the price ranges between \$3,000 to \$6000 with a maximum of 70 degrees of field of view. Since the normal visual field is approximately 170 degrees with 100 degrees comprising the peripheral vision region, the visual field offered by visual aids in the market are low. Therefore, I wanted to design a visual aid that is affordable at the price range of \$20 - \$50 (50x - 125x less expensive than the most affordable options) and to have at least 120 degrees of freedom to mimic the human visual field by lessening the vision impairment.

## Materials and Methods

In this project, 0.45X wide angle lenses available for cell phone cameras and lenses with zero power (clear lens) were used in the development of the visual aid. Once sketches of the design were drawn on paper, the Computer Assisted Design (CAD) tool Fusion 360 developed by Autodesk modeled the design in 3D. The slicing software Cura maintained by Ultimaker sliced and exported the modeled visual aid for printing. The visual aid was printed with 1.75 mm PLA+ filament using the 3D printer Creality Ender 3 pro. A lens repair kit was later used for assembling the 3D printed parts of the glasses. Using 3D printing, 4.5 cm diameter RP discs were printed with a hole size of 1 mm, 3 mm, 5 mm, 7 mm, and 9 mm that correspond to varying levels of tunnel vision. For outdoor utility, sunglass lenses were added as an additional feature to the visual aid. Using these materials, experimental glasses (clear lens glasses with wide angle lens) and control glasses (clear lens glasses without wide angle lens) were built (Figure 1).

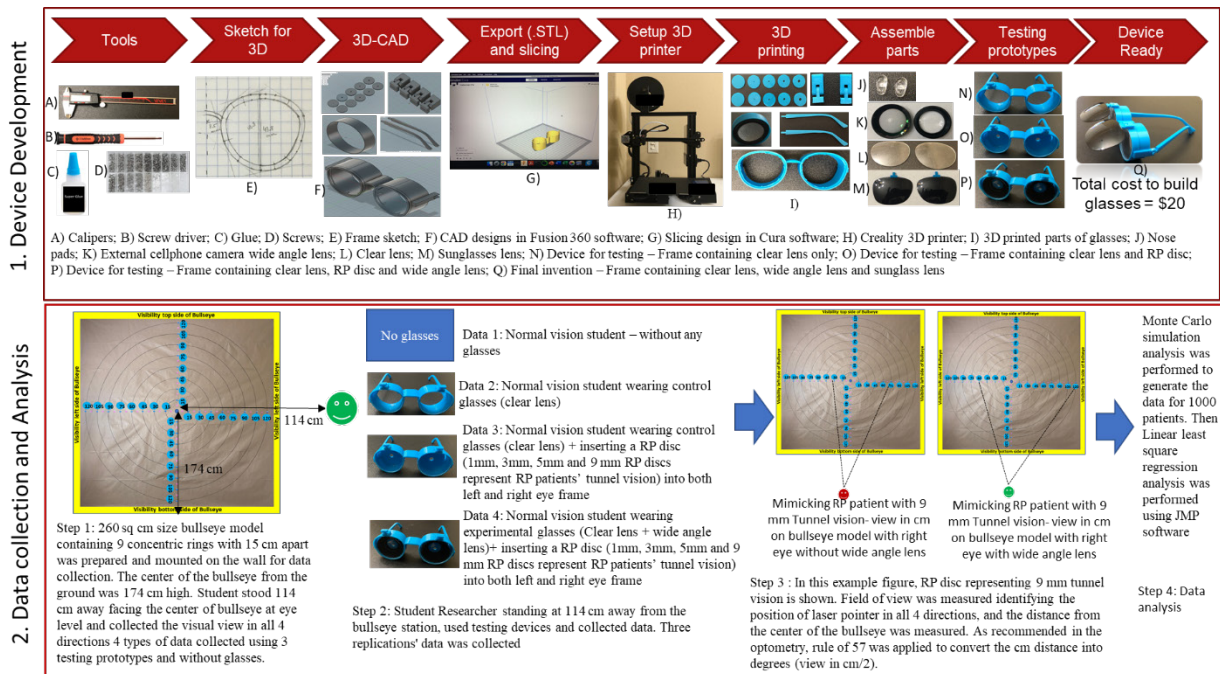


Figure 1. Steps involved in RP visual aid development, data collection and analysis.

## Bullseye model

A wall poster comprising an area of 67,600 square centimeters (260 cm x 260 cm) was prepared to create a bullseye model. Concentric rings with intervals of 15 centimeters were drawn and labeled for easy field of view measurements while seeing through the glasses. The student researcher having normal vision (20/20) collected data in all 4 directions of the bullseye (left, right, up, down) while keeping the head in a neutral position and the eyes fixed to the center of the model. This is a standard data collection procedure in the field of optometry (Woods et al., 2010). The student researcher stood 114 cm away facing the center of the bullseye at eye level and collected the visual field view data in each direction (Figure 1). First, the student researcher collected visual data without wearing any glasses. Next, the researcher collected visual data wearing the control glasses to detect any visual limitations while wearing the visual aid. Next, the researcher collected visual data wearing the control glasses and inserting the RP discs into the visual aid. Lastly, the researcher collected visual data while wearing the experimental glasses (control glasses + wide angle lenses) and inserting the RP discs into the visual aid. This procedure isolates the effect of the wide-angle lens to truly determine whether a significant visual gain can be achieved utilizing common wide-angle lenses. With the help of the designated scientist, a laser pointer was used to precisely pinpoint the visual field achieved during the testing procedure. The data consisting of three replications was collected. Finally, the rule of 57 in optometry was applied to convert the cm measured values into degrees of field of view.

## Variables tested

Independent variables: Experimental glasses containing the wide-angle lens

Dependent variables: The degrees and the area of visual field

Control group: Simulated RP patients with different visual fields using glasses without wide-angle lens (called as control glasses)

Constants: Bullseye target, surrounding lighting, fixed distance of 114 cm distance from the target bullseye, visual aid frame design identical between the control and experimental glasses with only difference being the utilization of wide-angle lens in experimental glasses (Figure 1).

## Data Analysis

Quantitative data collected in centimeters depicts the area that is visible with different severity levels of RP. The percent increase in the visual field between the control and the experimental glasses were calculated to highlight the possible improvement in peripheral vision. The data should suggest which wide angle lens is optimum for a particular tunnel size problem. This data was used as a reference for a Monte Carlo simulation analysis to generate data for 1000 patients. Linear least square regression analysis was performed using JMP software (Figure 1).

## Results and Discussion

### Low-cost visual aid

The total cost of materials required for the construction of the visual aid ranged from \$15 to \$22. Each external wide-angle lens used for cell phone photography costs between \$2 and \$10 depending on the size and magnification required. The idea of using cell phone wide angle lenses reduced the cost significantly. A custom 3D-printed frame also reduced the price. With a \$20 PLA+ filament, hundreds of glasses could be printed. Screws and nose pads kit cost from \$2 to \$10, and the materials provided were enough to assemble dozens of glasses. The visual aids in the market cost between \$3000 to \$6000 and have a wide range of features including magnification, viewing live scenes from surroundings, enhancing facial recognition, and limited peripheral vision. However, for a common individual, these glasses are simply not affordable and include many features that are not required for carrying out daily tasks by the RP patients. In addition, available RP visual aids are very bulky and, therefore, may not be comfortable to wear. Some of the reverse telescope-based glasses available in the market must be mounted onto regular glasses and are not functional on their own. The visual aid developed in this study is helpful for carrying out routine tasks such as commuting to the workplace, reading books, and walking independently. As a standard procedure, any visual aid must go through a critical evaluation through clinical studies (Szlyk et al., 2000; Woods et al., 2010). After a thorough evaluation in clinical studies for the safety, quality, and utility of this visual aid, perhaps these glasses could be recommended for RP patients. The student-developed visual aid has incredible applications for patients suffering from peripheral vision loss including genetic disorders like Retinitis Pigmentosa. Moreover, people in developing and under-developed countries can potentially afford this product because of its simple design and robust application.

### Product development and validation

To measure the effect of wide-angle lenses to improve peripheral vision, two types of glasses (control glasses containing only clear lenses and experimental glasses containing both clear lenses and wide-angle lenses) were built. Identical frames were designed, and other features such as the sunglass lenses were added to both frames to isolate the effect of the wide-angle lenses on visual gain (Figure 1).

The student data collected was validated to test how much improvement in peripheral vision was achieved. The data collected in centimeters on the bullseye model was converted to degrees, so that the visual field gain could be represented in a standard way. Because of COVID-19 pandemic restrictions, the visibility data could not be collected on real RP patients. However, the student researcher decided to create his own

method of testing tunnel vision by designing “RP discs” of varying size holes described in the methods that correspond to real world RP patients. The data from the control glasses were compared with the experimental glasses. The data revealed that the field of view was almost twice in experimental glasses containing wide-angle lenses compared to control glasses without wide-angle lenses. Since both glasses have the same design with the same components, the effect of the wide-angle lenses was very clear. The student-developed visual aid is simple, yet powerful, by targeting the most important need of RP patients: peripheral vision loss. For a patient with a 45 degree visual field, these glasses can provide 85 - 90 degrees of visual field, which is greater than the better performing visual aids available in the market.

Data collection is a strenuous activity and might result in errors because of eyestrain. Data consisting of three replications was collected at different times to potentially reduce these errors. Furthermore, collecting data while keeping the eyes fixed throughout testing was very challenging and might be prone to errors. However, literature suggests that “multiple replications tend to reduce such errors as much as possible” (Vargas-Martín and Peli, 2006).

Linear Regression analysis confirmed that there was a significant increase in visual gain using wide angle lenses. The average of 3 replications data was used to perform the regression analysis. The results were truly impressive: 7 mm tunnel vision can be corrected to the equivalent of near normal field of view using the student-developed visual aid (Figure 2). No significant visual difference was observed between the right and left eye. Overall, the horizontal vision gain (left to right) was significantly more than vertical vision gain (up and down) in both normal vision and simulated RP vision utilizing both the control and experimental glasses.

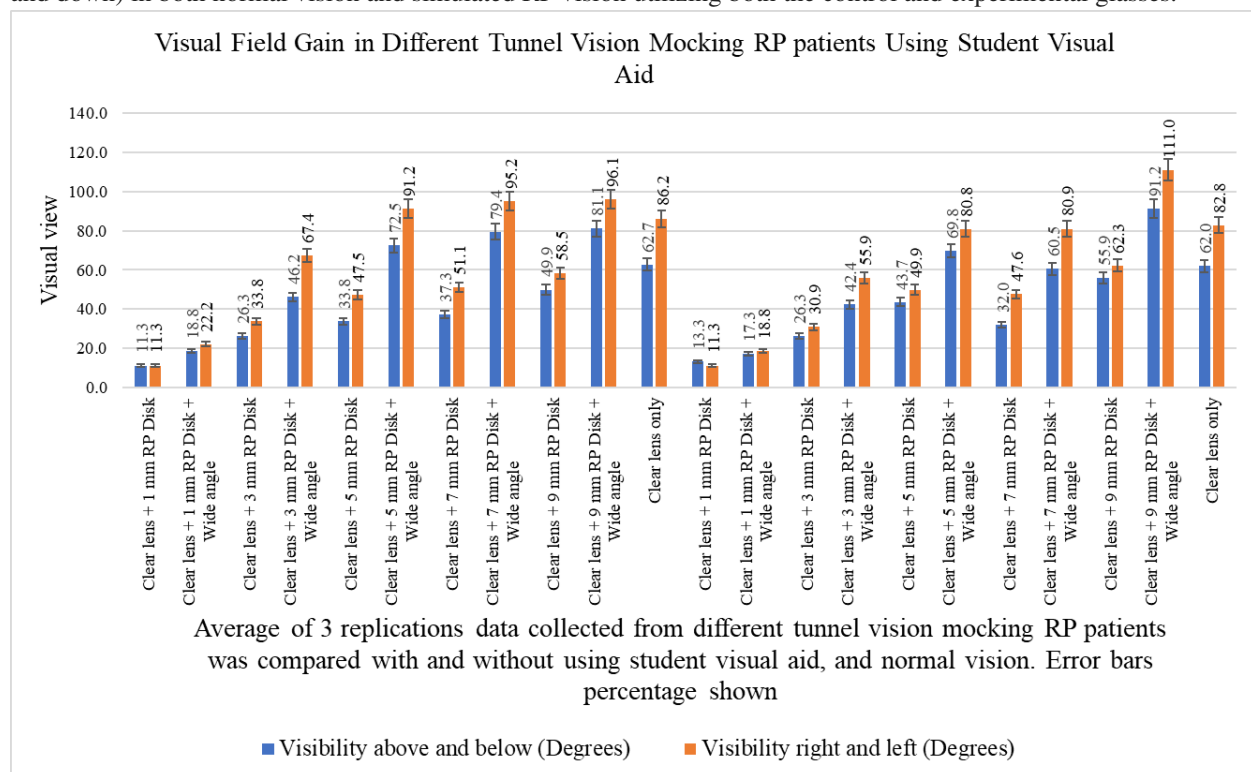


Figure 2. Visual field gain in different tunnel vision mocking RP patients using student visual aid

Monte Carlo simulation was carried out to generate 1000 RP patients’ visual field view data for both left and right eyes using the student collected actual data from the bullseye model (visibility above bullseye, below bullseye, left of bullseye and right of bullseye) with and without RP discs. The simulation data was used for the linear least square regression analysis. A very high F-ratio (>15966) and extremely low p-values

(<0.0001) show a statistically significant increase with the application of wide-angle lenses. Also, a high R<sup>2</sup> value (>0.93) shows that a linear model is a good fit for the data (Table 1).

**Table 1.** Monte Carlo simulation and regression analysis

Response visibility	R <sup>2</sup>	F Ratio	P-value
Visibility above bullseye	0.946	19781.36	<0.0001
Visibility below bullseye	0.934	15966.42	<0.0001
Visibility left side of bullseye	0.961	27658.66	<0.0001
Visibility right side of bullseye	0.972	40168.40	<0.0001

## Discussion

In the last decade, several advances were made in understanding the molecular basis of RP. Gene therapy and NGF eye drops have shown improvement in RP in animal models. However, because of the complexity of the disorder, there is still no cure for RP (Birch et al., 2016; Falsini et al., 2016; Edwards et al., 2018; Cehajic-Kapetanovic et al., 2020). With the advent of artificial intelligence, many motion detection features can be added to upcoming visual aids (Younis et al., 2019). A device called the Intel RealSense Awareness Wearable (IRSAW) was developed (Brown et al., 2019), incorporating a camera over the belt that detects objects and measures the approximate distance in its field of view. Such devices open the doors to benefit a greater number of people, but such devices are simply not affordable for the common individual. The student glasses in this study targeted peripheral vision loss as a key issue to develop glasses that are affordable and can benefit a vast group of visually impaired individuals. The testing results of the student-developed visual aid is highly encouraging and has huge potential in improving the peripheral vision of RP patients. Eventually, the device must be tested on actual low vision patients to further validate this new visual aid in clinical studies.

An interesting result was found in the research conducted by Vargas-Martín and Peli in 2006. When walking, the patients with peripheral field loss did not increase their scanning eye movements to compensate for missing peripheral vision information, and their horizontal scanning is reduced due to a lack of peripheral stimulation from RP. These results showed that RP patients did not have a strong visual stimulation to the environment. Based on this research, it is possible that the student visual aid developed in this study has an additional benefit of providing peripheral vision stimulation to allow patients to react more quickly to their surroundings.

Lastly, another type of glasses known as Trifield glasses has been evaluated for benefits in mobility and peripheral vision (Woods et al., 2010). The Trifield lenses use a reverse-telescopic architecture to expand the visual field only laterally, which may be important in avoiding collisions with other pedestrians and some obstacles. The student visual aid was built on the principles of a reverse telescope to provide an increase in both the horizontal and vertical visual field unlike the Trifield glasses.

The RP glasses are based on a reverse telescopic architecture and perform the same function as a minifier. Hence, the visual acuity decreases proportional to the power of the telescope (0.45x). Thus, the results of testing indicate a near doubling in the field of view but a decrease in the visual acuity to compensate. Thus, this visual aid should primarily be used in an episodic manner where a patient periodically wears the glasses while performing independent activities.

## Conclusion

Despite so many advances in the biotechnology and biomedical fields, there is still no cure for Retinitis Pigmentosa. Fortunately, RP can be managed with the help of visual aids for some years. The student-developed visual aid can revolutionize the optometry industry because of its affordability, utility, and simple design. Different levels of RP disorder were validated using student-developed RP discs, and statistically significant results suggest that wide angle lenses can increase the visual field substantially and benefit most RP patients. In addition to RP, other conditions like glaucoma, stroke, and brain aneurysms also cause peripheral vision loss. Thus, the student-developed visual aid is not only helpful to RP patients but also to others who are suffering from peripheral vision loss. These glasses are useful in both indoor and outdoor settings. This basic version of the visual aid utilizing only wide-angle lenses is helpful to most visually impaired people. The combination of widely used smartphone wide angle lenses with a custom sized 3D printed frame to be readily affordable and to provide nearly 50 additional degrees of the visual field is novel and not found in the literature. In the future, an advanced version of the visual aid will be developed that is powered with artificial intelligence for object detection with voice feedback. Further steps are required for patent and clinical studies of the student-developed visual aid.

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