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Research paper

A Review on the Treatments for Monocular Visual Impairment for the Development of a Visual Aid

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Abstract

Amblyopia is the most commonly found monocular visual impairment in the world. This paper presents an initial investigation into developing a visual aid for monocular visual impaired patients. The investigations conducted in this paper include those from direct interviews from consultant ophthalmologist. Investigations include reviewing the principle required to be embedded into the visual aid such as the distance and depth perception. Stereoscopic cameras and algorithms are also further discussed to interlink with the concepts of depth perception. Monocular visual impairment can most of the time be caused by medical conditions like amblyopia or glaucoma, and rarely caused by accidents and external factors. Thus, existing treatments for amblyopia, the effectiveness and challenges of the treatment are also clearly investigated and scrutinized in this paper. Some of the existing treatments include refractive therapy, occlusion therapy, atropine injections, perceptual learning, pharmacological treatment and acupuncture. This study has provided a clear insight into the requirements of developing a visual aid, thus further addressing the challenges faced by the treatments in this impairment.

Keywords: *Monocular; Visual; Impairment; Aid; Amblyopia*

1. Introduction

Monocular vision impairment refers to having no vision in one eye with adequate vision in the other as shown in Fig 1. Amblyopic eye and myopia are examples of monocular visual impairment. Monopsia is a medical condition where depth perception is lost due to the disability, thus the vision is only perceived in two-dimensional [1]. Another type monocular visual impairment is known as amblyopic eye or lazy eye. It is also to be noted that amblyopic vision loss cannot be treated later on in life and thus adults with amblyopic visual impairment have no option of treatment but to live with the state they already are until the time of death [2]. The visual field is also significantly affected as compared to a binocular visual field as shown in Fig 2. A research in the United Kingdom also shows that the risk of serious vision loss affecting the non-amblyopic eye is at a much greater risk than previously assumed [3]. Existing treatments for monocular visual impaired patients are not emphasized due to the population of these disabilities, which is only 2% in the United States, although 1 in 10 children in Malaysia is affected by it. The only existing treatment for monocular impairment is for amblyopic patients, a patch is placed on the sound eye to train the disabled eye to reactivate its optic nerve (Figure 1). However, it is to be noted, this treatment is only valid for children. Adults suffering from this disabilities have no form of treatment, thus a development of a cost-efficient visual aid for monocular visual impaired patients is vital.

2. Related Work

In this section of the journal, all related works for this research is discussed; the main concept that is integrated into this project is depth perception and stereoscopic cameras. The integration of these concepts is vital to the success of this research.

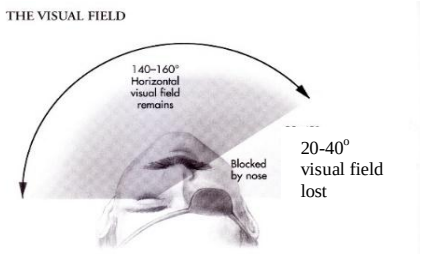

Fig. 1: Monocular vision [4]

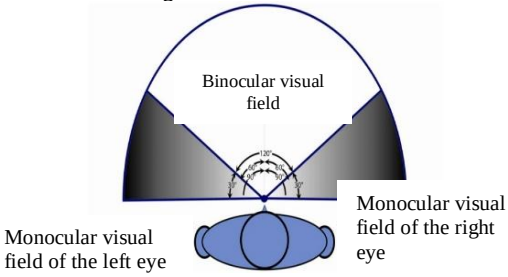

Fig. 2: Stereoscopic vision[4]

2.1 Distance and Depth Perception

Distance and depth perception is a vital ability required by a human to carry out simple daily tasks such as walking on a street or even crossing the road. The absence of this ability might lead to unwanted calamities. For instance, a person crossing a road might not be able to judge if a vehicle is approaching towards them or sighted at a distance. The National Institute for Rehabilitation

Engineering (NRE) has published a journal article on improving people's depth perception skills with optical aid for specialized occupation, safe driving and safe use for machinery, this study encourages individuals in an area of space to always have a spatial perception of the world around them [5]. Visually impaired people on the contrary often but not always develop effective distance perception skills.
Its been also clearly published by The National Institute for Rehabilitation Engineering (NIRE) on visual distance and depth perception that partially monocular people cannot drive with complete safety. This is because the image from the blurred eye on the person will superimpose the image produced by the sound eye. In these instances, the sharp and vivid image produced by the clear sound eye is degraded by the blurred vision of the bad eye[5].
Current treatments, however, suggest vision trainers, whereby trainers can train a person with monocular visual impairment to totally ignore the vision from the blurred eye. Nonetheless, some patients are conditioned, so the blurred images are suppressed while the outside vision is kept active on the poor vision side. Ophthalmologists also suggest having a lens fitted on the non-sound eye to occlude the images from it and avoid them being superimposed with the images produced from the sound eye. The special lenses are also able to partially or completely occlude the vision [6]..

3. Existing Treatments for amblyopia

3.1 Refractive Therapy

Refractive therapy is mostly recommended for children with amblyopia. Nevertheless, the therapy does not seem to be very effective as it depends on several other factors to determine its outcome. The compliance of the patient in wearing the glasses is the first challenge. As patients with amblyopia are mostly children of very young age, it is not possible to reach desired results in the desired amount of time. Thus, a study conducted by Atkinson et al.[13] shows that patients who were prescribed partial correction compared to those who have not undergone any treatment had the same process of emmetropization. Emmetropization refers to matching the axial length of the eye to the focal length of its optics. This balance is important in producing a clear image on the retina of the eye. Another challenge that is faced by this form is therapy is the condition in which the patient is presented on to. The baseline stereopsis levels very much influence the output of the treatment; a patient with a better baseline will have better chances of responding to the treatment and vice versa.

3.2 Occlusion

This is the most common treatment for patients with amblyopia. Occlusion is a therapy where vision on the sound eye is blocked and allowing the affected eye to reviving its vision back. Occlusion is only introduced by clinical experience rather than scientific based evidence. This had led to non-uniform hours of occlusion compliance for those with severe and moderate amblyopia. The Pediatric Eye Disease Investigator Group (PEDIG), a community committed to encouraging procedure for ophthalmologist, have changed the regulations as a result of these findings and suggest that those with moderate amblyopia use 2 hours of occlusion and multicenter clinical research in strabismus, amblyopia and another eye issue that affect kids sought to review this issue by conducting a study involving patients with severe and moderate amblyopia. Half of the patients with moderate amblyopia were recommended to have 6 hours of occlusion and the rest of the moderate amblyopia patients were recommended for 2 hours of occlusion. Results show that there was a significant difference in visual acuity for both occlusion hours. Thus the Royal College of Ophthalmologist, an international organization which moderates the standard operating severe cases require it at 6 hours of occlusion [14].

Fig. 3: Amblyopia patients using patches with cartoons embedded in it [15]

With most patients of amblyopia being children, adherence to patching or also known as occlusion becomes a challenge. Thus, interventions such as rewarding and decoration of the patch with cartoons on to it may ease the problem as stated in Fig.3. However significant the results were, it is impossible to obtain desired results of visual acuity of 6/9 and above in binocular vision. The chances of recurrence are also considered high in cases of amblyopia. A number of factors have been associated to recurrence of amblyopia such as better vision at end of occlusion treatment, a vast improvement during treatment, patient's history of recurrence and an inverse relationship of age and recurrence. Occlusion is also highly effective only during its critical periods, PEDIG reports that 50% of children from the age of 7-12 who underwent occlusion treatment had a much higher chance of significant improvement than those above the age of 12 [16].

3.3 Atropine

Atropine is a pharmaceutical to treat certain kinds of nerve specialist, pesticide poisonings, and a few types slow heart rate and to diminish salivation generation amid medical procedure[17]. It is also another common form of treatment for amblyopia, although not vastly used and recommended, it is often seconded by the occlusion therapy. Atropine is normally injected into the affected area using a sterile syringe. The functional model of atropine is such that it blurs the vision of the non-amblyopic eye by paralyzing the ciliary muscles that control extension and constriction of the pupil as illustrated in Fig 4. This treatment is very similar to occlusion just with the absence of the patch. It is however reported that the maximum blur visual acuity by atropine is only 20/100 in the non-amblyopic eye. Although it is reported, atropine is to be better accepted by the community than occlusion, it is still uncertain to mention if the treatment produces better outcomes as compared occlusion treatments [16].

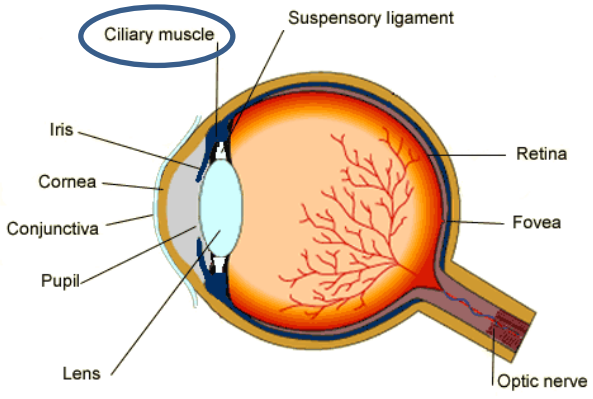

Fig. 4: Anatomy of the eye [18]

3.4 Perceptual Learning

Perceptual training involves training patients on perceptual tasks in relating and becoming aware of something through the sense of vision with the Cambridge Visual Stimulator (CAM) [19] as shown in Fig 5, a system that uses high contrast rotating sine wave gratings. Perceptual training is highly regarded by patients who have passed the critical period, which has significantly lost them the chances of gaining an advantage, by occlusion or atropine methods. Initial reports do suggest a significant improvement in patients, however, the requires a long-term follow up [6].

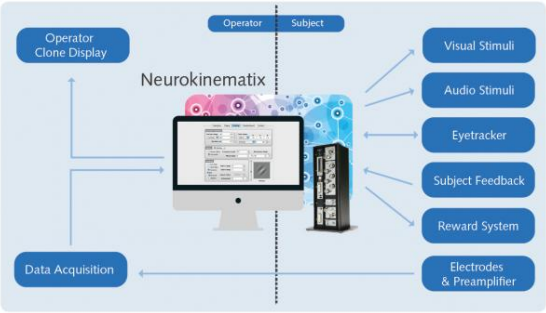

Fig. 5: Neurokinematix, an example of Cambridge Visual Stimulators[20].

During the perceptual learning treatment, an image is presented to both eyes, the amblyopic eye is presented with a high contrast image and the opposite is presented to the non-amblyopic eye as shown in Fig 6. A dichoptic game format is commonly used during the treatment. Initial data shows significant improvement of visual acuity 6/12 and above and stereopsis in the almost 58% of the patients[21]. However, no analysis has been conducted to explore the effects of the cause of amblyopia on visual outcome [22].

Fig. 6: An image on the left is of low contrast and on the right is a high contrast image [23]

3.5 Pharmacological Treatment

Pharmacologically, a common drug known as Levodopa most commonly treats amblyopia; it is a precursor to dopamine. Dopamine is one of those chemicals that is responsible for transmitting signals between the nerve cells (neurons) of the brain. Thus, Levodopa suppresses the neuron signals from the eye to the brain acting as an occlusion [16]. A notable amount of results has been noted by using these forms of drug treatments in terms of occlusion. Visual acuity has improved to 6/12 and above, as well as other visual functions, have also equally improved [24]. Carbidopa is a medication given to individuals with Parkinson's disease, keeping in mind the end goal to inhibit digestion of levodopa [25]. Carbidopa is also commonly used concurrently with the intake of Levodopa to increase the intake of it into the blood-brain barrier. The blood-brain barrier is a selectively permeable membrane, which separates the blood from the spinal fluid.

3.6 Acupuncture

The use of acupuncture for the treatment of amblyopia is still in its premature stages. Acupuncture is commonly used to improve the blood circulations at certain points in the body known as acupoints [26] as shown in Fig 7. In a recent study by Lam et al. where two groups were investigated, one group underwent occlusion therapy while the other underwent acupuncture therapy. After 15 weeks of the experiment, it is noted that the group with the acupuncture therapy had a much more significant result as compared to the occlusion therapy [27]. However, it is to be noted that with acupuncture therapy, more clinical- visits are required as it can only be done by trained healthcare professionals compared to occlusion.

Fig. 7: A child with amblyopia with acupuncture treatment [28].

3.7 Challenges and Effectiveness of Existing Treatment

Patching has been used as a form of amblyopic treatment for hundreds of years until today. However, the compliance with it that assures its efficiency is poor. It is been proven that although two-thirds of children might show some improvements in a quarter of a year the remaining quarter might regress once the patch is removed. The mechanism on how patching works is undefinable besides the simple understanding of training the unsound eye. The in-depth concepts of however is still not yet understood properly[10].

Dichoptic training and contrast balancing as shown in Fig 8, has been known to be the latest forms of treating amblyopia. This hybrid form of treatment has very much proven itself in improving monocular acuity; however, its usefulness to regain binocular vision and stereopsis is still very much unclear[11].

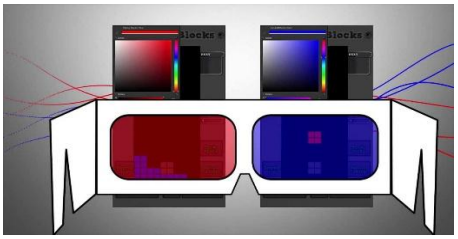

Fig. 8: Dichoptic training and contrast balancing depicting a hybrid treatment [12].

Achieving desirable outcome of amblyopia is almost an impossible task achieved by clinicians. This is because achieving optimum visual acuity to the fellow eye is often difficult in most of the patients. This is due to the introduction of these amblyopia treatment methods, which was introduced through a systematic review of whereby trial and error methods were practised, rather than a scientific review, which has more facts behind it.

4. Stereoscopic Cameras and Algorithms

Depth perception is vital for monocular visual impaired patients, thus a study by the department of informatics at the University of Genoa on the calibrated depth is reviewed. In this study, RGB-D cameras were used, as a high degree of precision is required to identify a stereoscopic 3D environment. Calibration was also a

vital procedure to improve the accuracy of the 3D measurements. Quantitative measurements were taken to validate the proposed approach [7].

Misalignments in stereo images lead to a high level of discomfort to the viewer's eye, as proven by Di Zhang et al.[8] work on the 3D visual discomfort assessment by measuring the vertical disparity tolerance. The experiment was conducted with 17 subjects with varying vertical disparity, stimulus angular sizes and luminance. Based on the results of the experiment conducted, a regression analysis was carried out to estimate the Vertical Disparity Tolerance (VDT) levels as a function of luminance and stimulus angular size. VDT is a recognized reliable indicator of visual comfort due to vertical disparity and the model can be used to predict visual comfort for given viewing conditions [8].

The depth perception model also has to be guided by visual comfort to obtain a clear visual salience, the perception of which an object stands out from the rest. The proposed saliency model by the study of Qiuping Jiang et al. composes of three components, which are 2D image saliency, depth saliency, and visual comfort based saliency. Color, texture, and spatial saliency compute and fuse to derive a 2D image saliency. The disparity in the image from the stereoscopic camera is used to compute depth saliency and stereoscopic image pair recognizes the visual comfort level. The final 3D saliency map is obtained by computing all three components. This acts as a vital algorithm to obtain the appropriate saliency model for the Visual Aid in this study [9].

A stereoscopic algorithm is however being generated in Python with the aid of a computer vision library to produce a saliency map which uses images from stereoscopic cameras. The image produced from this program is developed by stereoscopic block matching technology (SBM).

5. Conclusion

Monocular visual impairment has become a serious issue to look into in the recent years. It is a necessity to produce a visual aid that can aid the visual impaired patients with stereoscopic views. The gap found in this review is to produce a visual aid with increased field of vision and depth perception. Stereoscopic displays have become popular especially with its capability of 3-D image content, which is also able to produce depth perception, which enables us to distinguish depth and distance. In this paper, we have presented the challenges faced by the existing treatments for amblyopia patients as most monocular visual impairment is caused by this medical condition. The severity of amblyopia is also increased with age, as the chances of recovery become much lesser which increases the need for the development of the visual aid. The practical implementation techniques to produce a visual aid to address this problem includes a stereoscopic camera which is projected on to a monocular display on to the patient's sound eye which has increased the field of vision and enhanced depth perception and distance. The concept of the design would seem like a Virtual Reality (VR) Box, which has less strain to the sound eye. Ms Geetha an optometrist from the Tun Hussein Onn Eye Hospital (THONEH) has also suggested to include a flip hinge concept on the visual aid to make it look more aesthetic and user-friendly.

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