Myopia: How it Became a Modern Epidemic

Francesca Philips
Maths 89S Duke University
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Myopia

Introduction

Myopia is the most common ocular disorder with approximately 25% of the world’s population suffering from this condition (Rose, 2008). It is more frequently referred to as near sightedness; objects further from the spectator appear unfocused in comparison to the clarity with which near objects are perceived. The prevalence of myopia varies significantly in different regions of the world. Among young people in East and Southeast Asia, the rate of myopia has reached epidemic proportions. In Taiwan, approximately 85% of people under the age of 16 have the condition, and similar statistics exist in areas such as Singapore (74%) and Hong Kong (80%) (Fan et al., 2004). Sight-threatening high myopia is approaching 20% in these locations (). In the United States, the prevalence of myopia in young adults is approximately 50% (Ossolo, 2016). While lower in many Western countries, rising trends in all parts of the world are alarming, as seen in Figure 1. Having recognised the prevalence of myopia, this paper considers the nature of the condition, the development of it, as well as a review of seminal research into the mechanism of its progression. Multifactorial causes of myopia are further evaluated in light of current studies.

This increase in rates of myopia is of serious concern. Myopia is associated with a higher risk of permanent visual impairment, blindness or sight-threatening diseases such as cataracts, glaucoma and retinal detachment (Rose, 2008). There are also disadvantageous socio-economic
considerations that should be taken into account. According to Holden: “Earlier onset of myopia increases the lifetime economic burden related to loss of productivity and independence…” (Holden, 2016).

**What is myopia?**

Myopia can be axial, refractive, or a combination of the two. Axial myopia occurs when the eyeball is too ‘long’, as in Figure 2. The myopic eyeball is less spherical than the ‘normal’ eyeball, and is more stretched out lengthways. The length of the eyeball is such that the light focuses at a point in front of the retina. Refractive myopia occurs when the cornea or the lens of the eye bends light too much (Fernández-Montero, Olmo, & Olmo-Jimenez, 2015). The result is the same; with the light being focused in front of the retina. The images that photoreceptors in the retina send to the brain are distorted, impairing vision (Flitcroft, 2013).

**Eyesight in Early Life**

People are normally born with somewhat hyperopic, or ‘farsighted’, vision; however, with ageing, this tends to be normally corrected. In the first year or two of life, a process called ‘emmetropisation’ occurs, in which the eyeball is changing to decrease the amount of refractive error. Refractive error occurs due to distortions in the shape of the eye (Norton & Siegwart, 2013). Emmetropia is the refractive state in which the length of the eye is correctly matched with the focal length of the optics such that the light is...
refracted directly onto the retina and a clear picture is obtained. Emmetropia is the goal of emmetropisation, and is the refractive state of a ‘normal’ eye (Wang, 2011).

The process of emmetropisation is relatively complex. The young eye uses visual information in order to determine the requisite growth and development of the eye. Some two years after birth, the cornea remains stable, but the axial length of the eye continues to change (Morgan & Rose, 2005). This indeed is why axial myopia is most common; the axial length continues to change for approximately twenty years. It is also for this reason that myopia most commonly occurs before early adulthood, as by this point, the refractive state of the eye is mostly stable.

The process of emmetropisation suggests that there is a feedback loop which controls eye growth and refractive state. Refractive errors in the eye, myopic or hyperopic, occur when there is failure in the process of emmetropisation, or when an already emmetropic eye fails to remain that way (Flitcroft, 2013). It has been suggested by Flitcroft that there is “almost a process of homeostasis that occurs”, where the body attempts to match the axial length of the eye to the position of the retina.

**Monkey Experiment**

Evidence for this feedback loop can be found in the 1977 seminal study carried out by Wiesel and Raviola on macaque monkeys. Monkeys of ages ranging from just born to several years of age had their eyelids closed by suture, in order to investigate whether eye growth was influenced by visual experience. If eye growth and development was controlled purely by genetics, then the fusing of lids should not have had an impact on the axial length of the eyeball or caused axial myopia.

It was discovered that there was a positive correlation between the degree of myopia and the duration of closure, as well as between the degree of myopia and early age of closure (Wiesel &
Raviola, 1977). The monkeys whose eyelids were stitched at birth developed a high degree of myopia, while those whose eyelids were fused when they were mature did not develop myopia. The refractive error was also less in those instances where lids were closed for a shorter period of time. This can be seen in Table 1, where the monkey whose eyes were fused at birth developed a -2.75 dioptre difference in refraction, while the monkey whose eyes were fused when mature experienced no difference in refraction (Wiesel & Raviola, 1977). The myopia that the lid fusion caused was axial; the eye elongated and caused the light to focus in front of the retina, but the cornea remained relatively unaffected. However, this myopia in particular is called deprivation myopia, as it occurs when there is visual deprivation (Wiesel & Raviola, 1977).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Interocular difference in refraction and axial length following neonatal lid fusion in macaque monkeys</th>
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<tbody>
<tr>
<td>Experiment no.</td>
<td>Age at lid fusion</td>
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<td>1</td>
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<td>Birth</td>
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<td>7</td>
<td>12 months</td>
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<td>8</td>
<td>mature</td>
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*Expressed as a ratio between axial length of the myopic eye and axial length of the normal eye.

**Chicken Experiment**

While Wieser and Raviola’s experiments showed that eye growth was influenced by visual experience, it did not indicate whether optical tuning was occurring. It did not show if the feedback loop was tuning the axial length of the eye to the strength and curvature of the cornea and lens.

Schaeffer, Glasser and Howland’s 1988 experiment aimed to answer these questions and involved raising chickens with defocusing lenses of differing powers in front of their eyes.
Small leather masks were fitted to the chicks’ heads, with lenses attached to the masks using velcro fasteners. These lenses were used to defocus the chickens’ eyes during the first thirty days of their life, and were of varying strengths (Schaeffel, Glasser, Howland, 1988).

The experiment found that the axial length of the eyes that were treated with negative lenses was higher than those treated with positive lenses. The negative lenses created a condition in which the light was focused behind the retina, and so the feedback loop responded (Schaeffel, Glasser, Howland, 1988). This resulted in longer eye length to compensate for the negative optical power that was imposed on the chickens.

**Why does myopia occur?**

It is generally agreed that myopia is multifactorial and is a function of both ‘nature and nurture’ (Hepsen, Evereklioglu, & Bayramlar, 2000); however, the majority of cases of myopia in economically developed countries are thought to be caused primarily by environmental factors such as urbanisation, education and lack of time spent outdoors.
Sunlight and the ‘Light-Dopamine Hypothesis’

Recent studies link development of myopia to a lack of sunlight or time spend outdoors, showing that children who spend less time outdoors are more likely to be myopic. This finding is unaffected by the amount of near work that a child does or genetic factors such as if the parents are myopic (French, Ashby, Morgan, & Rose, 2013).

One explanation for this is provided by the ‘light-dopamine hypothesis’. A 2008 study by Rose suggests that increased light intensity causes a release of dopamine from the retina. Dopamine is known to be able to reduce axial growth in the eye (Iuvone et al., 1991; McCarthy et al., 2007). This hypothesis has been supported by a number of animal experiments which tested the effects of bright light on the development of myopia. When tested, chickens that were exposed to higher illumination levels for longer periods of time had far lower rates of myopia than those raised in normal laboratory lighting levels (French, Ashby, Morgan, & Rose, 2013). Experiments on tree shrews concluded similar results, with approximately 40% lower rates of myopia for those that were exposed to high illumination levels (French, Ashby, Morgan, & Rose, 2013). However, one piece of evidence that is inconsistent with this hypothesis is that similar experiments on monkeys had limited effects on rates of myopia. It is generally agreed that the latter findings are more significant, in that monkeys are more indicative of the likely effects on human myopia. At the same time, results are not entirely conclusive, and suggest further research is needed.

Computers and Myopia

It is often assumed by the commentariat that modern technological devices, such as computers and hand held electronic screens have been an important factor in the growth of the epidemic of myopia; however, this is in no way supported when considered over time. Growth trends throughout South
East Asia picked up pace prior to the wholesale emergence of these technologies (French, Ashby, Morgan, & Rose, 2013). An assessment of the impact of these technologies is at the same time made more difficult by the fact that their usage goes hand in hand with less outdoor activity!

**Looking to the Future**

The prevalence of myopia is extensive throughout the world and most marked in South East Asia; moreover, the growth trend of the condition continues unabated (Morgan & Rose, 2005). This is in spite of an increasing and fairly good understanding of the nature and causes of it. Research suggests there are steps that could be taken to alleviate the extent of future generations taking on current levels of myopia. At the same time, the reality is that many of these steps involve significant behavioural changes that are extremely difficult to bring about in practice. How realistic is it to expect modern society to halt trends to spend less time indoors at work or at home? It is most likely that could be achieved by leveraging off other related trends in modern society such as increased outdoor fitness or adventure activities as leisure time rises in society. There is a further problem, however; given that the greatest incidence of myopia occurs in the young, this is a situation which is unlikely to be rectified in any meaningful way in most people’s lifetimes. It is not unreasonable to consider therefore longer term potential solutions resulting from technological breakthroughs in medical science.
Bibliography


