EC OPHTHALMOLOGY
Brief Review

Time Course of Nearwork Myopia

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Abstract

Purpose: The objective of this report is to predict the negative drift response of a student's refractive state (i.e. progressive myopia) R(t) [Diopters] over the course of several years following a step increase of near point study hours.

Methods: First order differential equations are used to predict the eye's control system response to the nearwork demands of the student's study environment. Variable student work load is modeled as an oscillating negative square wave, corresponding to 2 hours nearwork during the morning, 2 hours during the afternoon, and 2 hours in the evening. Rather complicated differential equations can be solved using a simple resistor-capacitor R-C analog series circuit, responding to both AC and DC applied voltages.

Results: Often a high school, college, or graduate student will accumulate -0.5 to -1.0 diopters of myopia per year over a 4 year period. Using basic control system equations, slowly responding as an exponential function R(t) with time constant k = 2 years, it is shown that progressive myopia accumulates as a natural consequence of the eye responding to daily nearwork demands.

Conclusions: Practical applications include using ordinary reading glasses during study, strength +2.00 to +3.00 diopters, to partially offset (i.e. cancel out) the -2.00 to -3.00 diopter applied work load of the nearpoint environment. Hard working engineering students, MD students, Ph.D. graduate students, and MD/Ph.D. graduate students are particularly susceptible to myopia, often accumulating -2 to -3 diopters of additional myopia during their 4-year academic course.

Keywords: *Feedback; Emmetropization; Myopia; Reading Glasses; Analog Circuit*

Introduction

Nearwork has been proposed as a factor in myopia progression. Near work, such as intense computer work, can increase myopia. Feedback Theory predicts a causative relationship between nearwork and myopia, as nearwork is equivalent to added minus (negative) lenses while looking in the distance. The nearwork dioptric value, or the dioptric value of the equivalent lens, can be added as a step input to the first-order feedback system, which responds by increasing the amount of myopia.

Methods and Results

The purpose of this report is to present a simplified mathematical model of progressive myopia. This model for refractive error development of the human eye requires that there is an optical signal equal to the refractive error, which in turn corrects the refractive error of the eye. The first-order feedback system used here, defined by the transfer function $F(s) = 1/(1+ks)$, was first proposed by Medina and Fariza in 1993 [1].

A simple R-C analog circuit is presented to solve the resulting 1st order equations, and to illustrate how near work causes a myopizing progression, additional to that created by the negative lens applied to the eye to correct myopia. This analog-circuit technique is a general result, which as a practical matter can account for many different variations of parameters and initial conditions. Here, a -5v battery is used to simulate a 5 diopter corrected myope, and a -3v square wave simulates nearwork. The system response to under-correction or reading glasses is given by simply replacing the -5v battery with a lower voltage battery. Basically, this is a matter of an ordinary R-C resistor-capacitor series circuit responding to negative DC and AC applied voltages.

Discussion

An electric circuit for example can simulate myopia progression vs. time R(t) because the response of the feedback system to a lens step input is the same as the capacitor voltage in a R-C (Resistor-Capacitor) circuit, as shown in figure 1. When near work is involved a negative square-wave represents the negative lens equivalent to the accommodative demand, as represented in the inset figure 1.

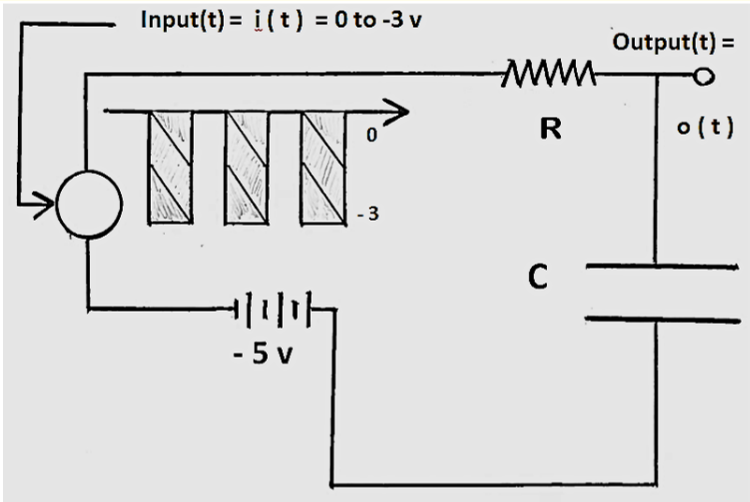

Figure 1: *Electrical circuit shows the refractive development as the voltage at the capacitor of a corrected -5D eye, periodically reading at a distance of 1/3 meter (14 inches).*

In order to numerically solve, this is a fairly complex calculation. The R-C circuit solves the problem without any computations (Figure 1). The system exhibits an exponential progression of the capacitor voltage o(t) [or refraction R(t)] [1,2]:

$R(t) = -5 - 3\,[1 - \exp(-t/k)]$ Equation (1)

where t is time, k = 2 years is the time constant and R is either refraction or voltage. This equation applies initially when the square wave is at -3, and then exponentials alternating with the square wave apply as described in [2]. This electrical circuit simulates myopia progression vs. time as the voltage at the capacitor, where Volts (V) represent Diopters (D) and a negative square-wave represents the effect of intermittent near work, equivalent to the use of a negative lens. The area under this negative square wave represents the accommodative demand or number of accumulated diopter-hours, an important optical workload factor influencing juvenile myopia, Mutti *et al* * while its time average is defined as the "near demand", in diopters, which is equivalent to the negative lens that will cause the myopia progression.

The use of this analogy illustrates how near work triggers a myopizing progression [3,4] additional to that created by the negative lens applied to the eye to correct myopia. This analog-circuit technique is a general result, which as a practical matter, can accommodate many different variations of parameters and initial conditions. Hung & Ciuffreda present other circuit models of myopia development (+). For instance, the system response to under-correction [5] is given by simply replacing the -5v battery with a lower voltage battery [6-9].

(*) Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, near work, school achievement, and children's refractive error. Investigative ophthalmology & visual science. 2002 Dec 1;43 (12): 3633-40.

(+) Hung GK, Ciuffreda KJ. A unifying theory of refractive error development. Bulletin of Mathematical Biology. 2000 Nov 1;62 (6): 1087-108.

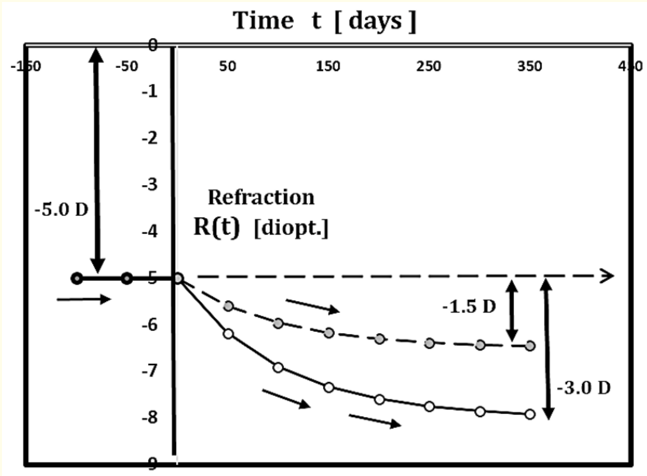

Figure 2: *Equation (1) evaluated with 100% reading (16 hours/day) at -3.0 diopters (lower exponential) compared with 50% reading (8 hours/day) (upper exponential). After several years have elapsed, an additional - 1.5 diopters of myopia will accumulate (R = - 6.5 diopters). A 25% nearpoint workload (4 hours per day) will accumulate -0.75 diopters of myopia. Time in weeks and R(t) in diopters. The curves represent the isolated effect of near work. Actual refraction curves of a patient will not be exponentials, but a straight lines because the new correction of the accumulated myopia will make it progress faster [8].*

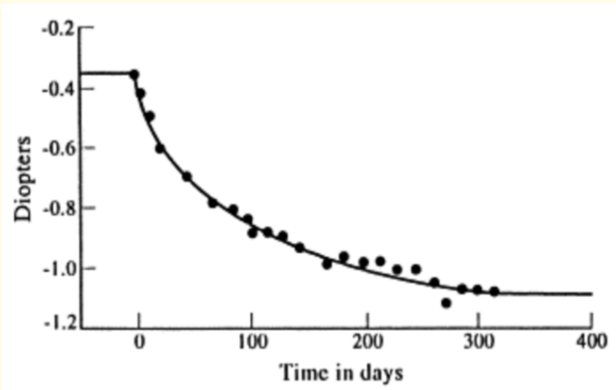

Figure 3: *Comparison of theory vs experiment for six adolescent Macaca nemestrina at -2.0 diopters. Correlation coefficient is 0.97 for t1 = 100 days. Theory agrees with experiment (±) 0.06 r.m.s. diopt. over 23 time intervals.*

Figure 4: *Illustration of the concept of "near demand". The Law Student is seen reading at an effective distance of -3.0 to -4.0 diopters. The time he spends reading determines the average accommodative demand or near demand, which could be around -1.5D diopters. Its effect is the same as if our law student wears a -1.5D lens continuasly. (By Norman Rockwell, from the Saturday Evening Post, Feb. 19, 1927.)*

Figure 5: *Reading glasses for a -5.00D. college myope. Add lenses are used in bifocals and progressive addition lenses, "PAL's". Basically, these reading glasses are near demand compensators, with a +3.00D add for reading.*

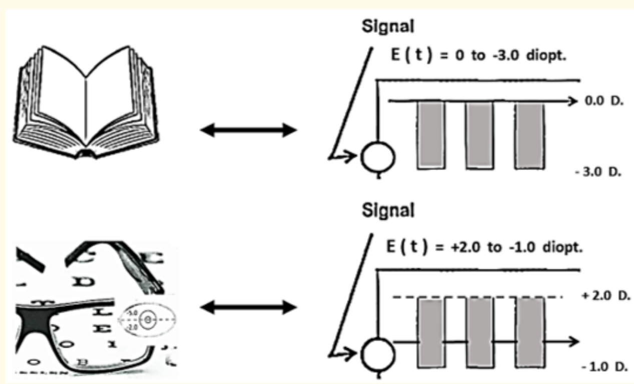

Figure 6: *Near demand required to read a book at a distance corresponding to -3.0D, one hour ON, one hour OFF is -1.5D, compared with the greatly reduced demand, using +2.0 diopter reading glasses, requiring only -0.5D of near demand.*

Conclusions

The negative going square wave (i.e. the applied optical work load, in units of diopters) in figures 1 and 6 deserves some additional comment. Three cycles are shown, corresponding to a typical day, representing the hour-by-hour applied work load experienced by the eye during the morning, afternoon, and evening of a typical work day. For instance, one might be reading for 2-hours on average at near-point range, and then doing distance (far-point) work for 2 hours, during each of these 3 intervals - morning, afternoon, and evening hours. This then averages out to ~ 1.0 to ~ 1.5 diopters of optical work, depending on the intensity (i.e. closeness of range) of the near work, and the strength of the distance (and when applicable) the reading correction.

Practical applications include using ordinary reading glasses during study, strength +2.00 to +3.00 diopters, to partially offset (i.e. cancel out) the -2.00 to -3.00 diopter applied work load of the nearpoint environment. Hard working engineering students, MD students, Ph.D. graduate students, and MD/Ph.D. graduate students are particularly susceptible to this type of myopia, often accumulating 2 to 3 diopters of additional myopia during their 4-year academic course (++).

Conflict of Interest Statement

The authors have no proprietary or financial conflicts of interest.

(++) Lin LL, Shih YF, Lee YC, Hung PT, Hou PK. Changes in ocular refraction and its components among medical students--a 5-year longitudinal study. Optometry and vision science, 1996 Jul;73 (7): 495-8.

Acknowledgement

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