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Research Article

3 Element Electrical Circuit Model of Stair Case Myopia

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Abstract

A 3-element minimal complexity AC/DC equivalent circuit is shown to represent the time course of progressive myopia during the student's educational years, consisting of a Resistor R, Capacitor C, Battery Vo, and ON/OFF switch. This circuit is accurate over several decades of myopia progression, typically age 10 to age 30, accounting for the average accomodation diopter-hours (work load) from near point study, periodic increases in the strength of negative corrective lenses, individual subject's time-constant response to the near work demands, and active myopia-control techniques, using positive (+) Add reading glasses during study.

Keywords: *Stair Case Myopia; Nearwork; Resistor-Capacitor-Battery Circuit; Diopter-Hours, Progressive Myopia; Reading Glasses*

Introduction

The fascinating problem of myopia progression is quite detailed, so far, it has not been solved, but researchers are making significant advances. It is now recognized that a part of the problem is inherited, and part is acquired during the educational years, as a result of over-working the visual system at near point [1,2]. Lin., *et al.* (1996) [3] show that graduate level myopia prevalence can exceed 95%, continuing to progress during graduate school i.e. l.c. s and u.c. F. Since progressive myopia can develop at just about any age, to almost any degree, it seems that the visual system follows the old adage, "It's not the age, it's the mileage!".

Literature Review

Guyton (1995) [4] reviews various aspects of the progressive myopia problem. Holden., *et al.* (2015) [5] review the alarming worldwide increase of myopia prevalence in recent years. Medina and Fariza (1993) [6] develop a first-order control system to understand the development of emmetropia and myopia. Greene., *et al.* (1996) [7] show the effects of daily nearwork cycles on the progression of myopia, comparing well with animal experiments [8]. Medina [9-11] discusses closed-loop and open-loop control system equations to predict the exponential and linear time course of uncorrected and corrected myopia development, respectively. Greene and Medina (2016, 2019) [1,12] develop an analog computer model of myopia development, which automatically solves complex control system equations in accelerated time. Greene, Grill and Medina (2016) [13] review the effects of excessive nearwork on myopia development during the college years. Brown and Berger (1979) [14], Hung and Ciuffreda (2000) [15], Greene and Medved (2017) [16] and Greene (2020) [17] develop analog computer circuit models to incorporate the effects of myopia, negative lenses, and positive reading glasses. Young (1961) [8]. experimentally shows the negative effects of a near point environment. Oakley and Young (1975) [18] present extensive data that bifocals

can control myopia progression. Cheng., *et al*. (2014) [19] review the effects of various new types of reading glasses, including progressives, in terms of slowing myopia progression. Troilo, Smith., *et al.* (2019) [20] present a complete review of current myopia research.

Materials and Methods

An analog series circuit (Figure 2a) is used to calculate myopia development, consisting of a resistor, capacitor, battery, and square wave produced with an ON/OFF switch or oscillator [17]. Each component represents a particular aspect of the visual system and environment. The resistor and capacitor represent the slow rate of the system to respond, in terms of the RC time constant τ, typically $0.3 < \tau < 4.0$ yrs. The battery (typically -3 to -8 Volts for -3.00 to -8.00 Diopter myopes) represents the optical power of the corrective distance lenses. Morning, noon, and night, the square wave reading demand, varying from 0 to -3 Volts (0 to -3.0 diopters), represents the intermittent near-point work environment of the student.

Specific time constants

The time constant τ of a series RC circuit is given by: τ[secs.] = R [Ohms] x C [Farads]. For the purpose of accelerated laboratory bench experiments, set R = 1,000 Ω, C = 1,000 μF, yielding τ = 1.0 sec. This very rapid laboratory time constant (1 year of myopia development is compressed to just 1 second) can only be employed and viewed using an oscilloscope and square-wave oscillator, to simulate the square-wave demand function. Selecting a slower R = 10,000 Ω and C = 10,000 μF yields τ = 100 seconds, allowing the hobbyist to use an ordinary voltmeter and ON/OFF switch to simulate and observe the time course of myopia progression.

For instance, during a typical day, a student (or office worker) might read at a distance of 13 inches (i.e. -3.00 diopters, or -3 Volts), for 1 to 2 hours in the morning, 1 to 2 hours in the afternoon, and 1 to 2 hours in the evening. Each time resting the visual system, at i(t) = 0 diopters (0 Volts), for these 3 intervals, 1 to 2 hours rest during each daily segment, with far point activities, including television, dining, coffee breaks, exercise, etc.

Results

Figure 1 shows a typical graduate student, age 22 to 26, studying at an effective optical distance of -3.00 to -4.00 diopters (-3 to -4 Volts). Figure 2a shows the 3-element equivalent RC series circuit, with an applied AC square wave, used to predict the time course of progressive myopia. Figure 2b shows the resulting Stair Case Myopia, with typical individual parameters, as the strength of the student's glasses is increased over the years. Figure 3 shows the positive effects of actively using reading glasses during nearwork study, considerably lessening the demands of the optical work load. Figure 4 shows that +3 Diopter reading glasses electric equivalent can reduce the effects of the negative battery from -5 to -2 Volts.

Figure 1: *Norman Rockwell "The Law Student", Sat. Evening Post, Febr. 19, 1927. Equivalent reading distance is -3 to -4 diopters.*

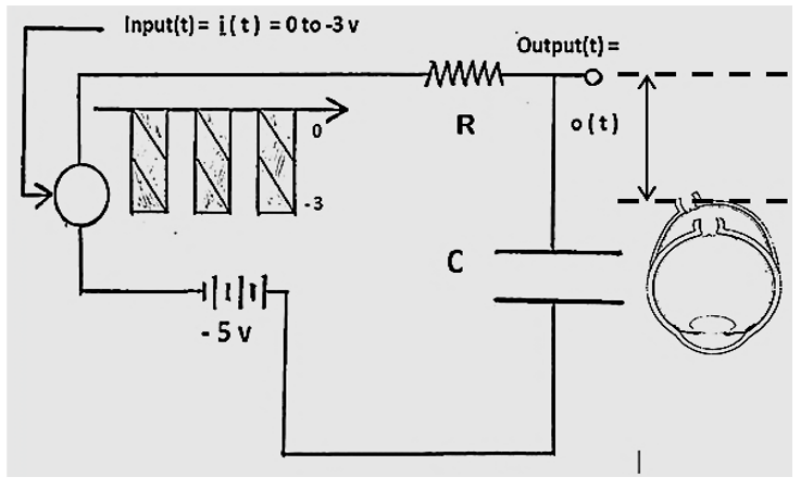

Figure 2a: *RC series AC / DC circuit diagram. i (t) = demand Input (t), o (t) = refraction Output (t).*

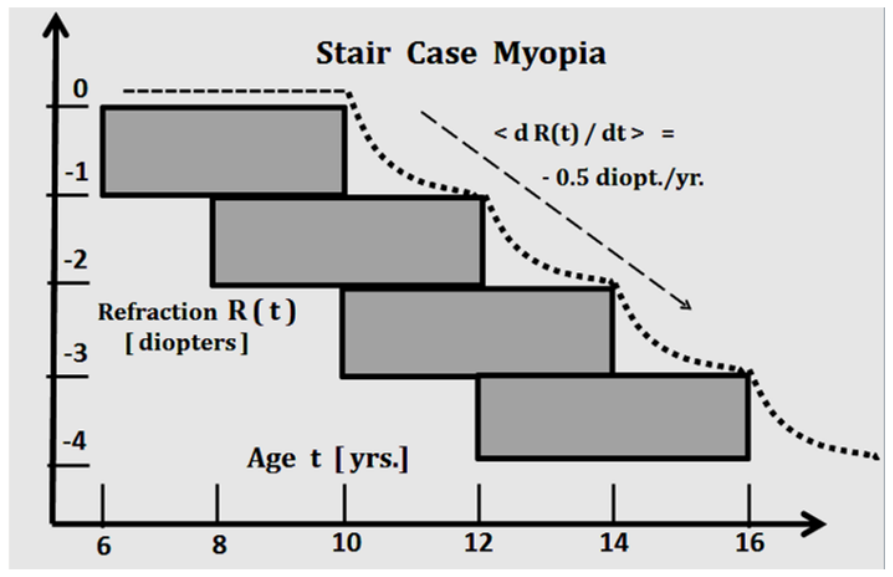

Figure 2b: *Typical parameters for students developing progressive myopia, including variable onset age 6 < t0 < 12 years, and variable progression rate -0.25 < R' < -1.0 diopters/yr.*

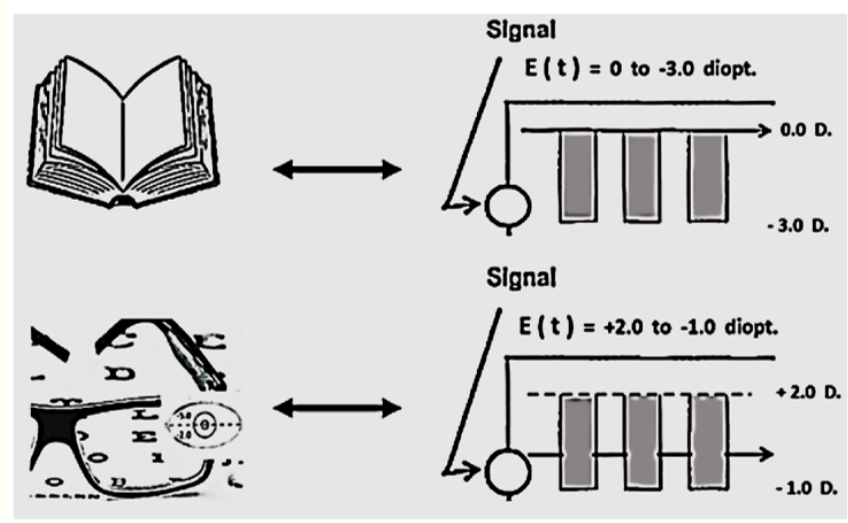

Figure 3: *Myopia attenuating effect of +2.00 D. reading glasses on magnitude of the square wave reading demand function [12].*

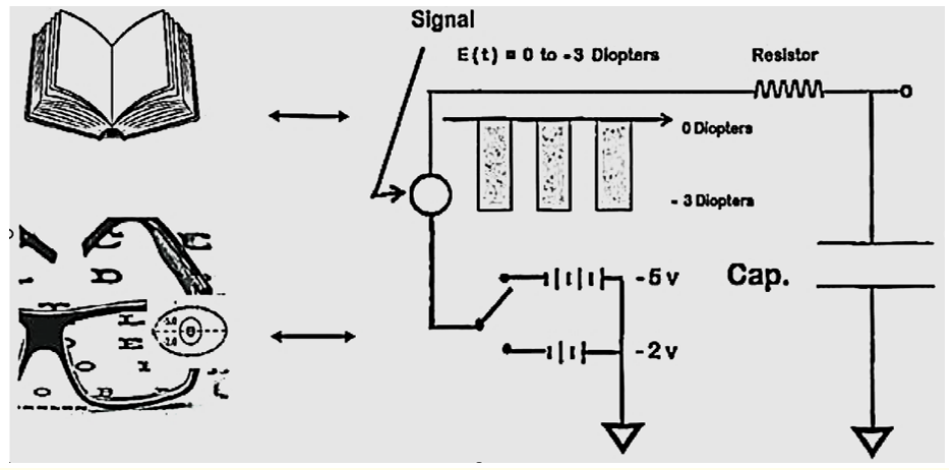

Figure 4: *Equivalent circuit shows the effect of +3.00 D reading glasses (reducing battery from -5 to -2 Volts).*

Discussion and Conclusion

Nearwork induced transient myopia (NITM) is the subject of extensive clinical and laboratory research in recent years [15,19,20].

The equivalent RC circuit: High school students and freshmen science majors at college are well versed with ordinary RC (Resistor Capacitor) circuits, in terms of circuit response to either DC (Battery = -Vo) or AC (Sine Wave = 0 to -Vo) applied loads. However, the

myopia problem is a little more complicated (Figure 2a), requiring the simultaneous application of both AC and DC voltages to the circuit. As a practical matter, solving these combined differential equations is difficult, but the series RC circuit (basically an analog computer) automatically solves these equations, predicting the time course of progressive myopia for years, in just a few minutes. The results can be observed with an ordinary voltmeter or oscilloscope.

As a practical matter, in terms of using (+) Add reading glasses, the student should consult with their ophthalmologist and/or optometrist, to obtain an Rx for reading glasses (single vision, bifocal, progressives, or clip-ons) with a +2.00 to +3.00 D. reading add.

Applications to high and pathological myopia: As shown in figure 2a, the effect of increasing degrees of myopia (greater than -5 to -6 diopters) is to stretch the posterior pole of the sclera, subsequently this can damage the retina, choroid, and optic nerve [5,20]. Figure 2b shows the classical stair case response of the eye's refraction, resulting from continual correction [9].

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