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Respiratory System Directly Influences Visual System: Scanlan's General Theory of Myopia

Paul J. Scanlan

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ABSTRACT: *Purpose.* I hypothesize that the respiratory system applies air pressure to the rear of the eyeballs influencing the shape of the eyeballs and hence influencing clarity of vision at different distances (refractive state). *Methods.* A review of published material and some basic observations combined with original thought. *Results.* A novel theory, Scanlan's General Theory of Myopia. *Conclusions*. The respiratory system directly influences the visual system. Scanlan's General Theory of Myopia explains some important but previously unknown or misunderstood aspects of the visual system (including the cause of myopia, the mechanism of accommodation and the role of blinking) and aspects of the respiratory system (including the role of the paranasal sinuses and implications of breathing pattern). The significance of this study cannot be overstated. Scanlan's General Theory of Myopia brings new understanding to the fields of vision science and respiration science and has major practical implications such as for the treatment of myopia.

Key words: vision, myopia, accommodation, blinking, respiratory system, paranasal sinuses, sinus, breathing, breathing pattern, diaphragm.

INTRODUCTION

Worldwide approximately 1,600,000,000 people are myopic (nearsighted).[1] The incidence of myopia is increasing. In some countries, myopia is the third leading cause of blindness.[2]

Current scientific debate centres on the cause and treatment of myopia. Many studies have shown that myopia is largely attributable to environmental rather than genetic factors.[3] The general consensus is that the environmental factor chiefly responsible for myopia is excessive near work, such as reading and computer use.[4]

The mechanism through which excessive near work leads to myopia is the main theme of this paper. The mechanism involves the respiratory system and is the basis of a new theory, Scanlan's General Theory of Myopia. This paper provides a brief explanation of myopia then considers the current understanding of the causes of myopia, including the weaknesses in the hypotheses on which that understanding is based. A new theory is outlined and supporting observations are put forward.

METHODS

The theory presented in this paper is based on a review of published material from a variety of fields and sources, together with some basic observations and critical reasoning. The author acknowledges that many of the publications referred to in this paper are second hand sources and welcomes corrections in respect of any misinterpretation of material contained in those sources.

DISCUSSION

What is myopia?

The process of vision involves light rays entering the eye. In a normal eye, these light rays are made to converge at a point on the retina, from where sensory impulses are sent to the brain for interpretation. Myopia is a condition where light rays entering the eye converge at a point in front of the retina.[5] The point where light rays converge is controlled by refraction (bending of light) through the cornea and lens, and consequently myopia is referred to as a refractive error. In layman's terms, myopia results when light does not hit the intended target inside the eye.

If a person has myopia, he or she is unable to see distant objects clearly. To achieve clear vision, the margin for error within the eyeball is very small. If the light rays refracted by the cornea and lens miss the target within the eye by an amount as little as the thickness of a piece of paper, then blurred vision will result.[6]

The literature refers to several different classifications of myopia based on factors including severity and age of onset.[7] Special forms of myopia such as that associated with Marfan's syndrome and other conditions involving severe biochemical malfunction are outside the scope of this paper.

Part 1. Current Theory and Its Weaknesses

There is a radical difference between the theory set out in this paper and much of the theoretical underpinning of current thinking about myopia (referred to throughout this paper as "the Current Theory"). A description in general terms of the main thrust of the Current Theory is sufficient to highlight weaknesses in the Current Theory and to illustrate the contrast between the Current Theory and the new theory set out in this paper.

The Current Theory includes a range of hypotheses about the causes of myopia. However, these broadly fall under two headings and may be summarised as follows. According to Current Theory, in a myopic eye, light rays converge in front of the retina because:
(a) the lens system is not functioning properly due to a spasm brought on by overuse - referred to as the hypothesis of functional myopia; and/or
(b) the eyeball is longer than a normal eyeball due to excessive growth or stretching by the oblique muscles – referred to as the hypothesis of structural myopia.

Some vision scientists believe that functional myopia and structural myopia may occur together.[8]

Functional myopia - spasm

Within the eyeball, light will be refracted differently depending upon the thickness of the lens. The lens changes shape from thin to thick due to the action of the ciliary muscle. The author notes that the elements of the focussing system include not only the lens and the ciliary muscle controlling the lens, but also the cornea and the front to back length of the eyeball (referred to as axial length).

Accommodation is the process of causing light rays entering the eyeball to converge at a given point and is achieved by interaction of the cornea, lens, ciliary muscle and axial length. Accommodation for near work requires tensing of the ciliary muscle, which causes the lens to thicken and bend light rays more sharply so that they converge at the required point on the retina. On the other hand, distance vision requires relaxation of the ciliary muscle. Compared to near work, light rays from distant objects are closer to parallel upon entering the eyeball. Therefore, for distance vision, the light rays do not need to be refracted as sharply in order to make them converge at the required point on the retina. Relaxation of the ciliary muscle causes the lens to return to a thin shape, and as required, the thin lens refracts the light less sharply.[9]

Proponents of the functional myopia hypothesis hold that overuse of the ciliary muscle, due to excessive near work, causes the ciliary muscle to go into a spasm so that it can no longer relax but only work within a set range. As a result of the spasm, the lens cannot achieve the relaxation required for distance work and the resulting refractive error is myopia.[10]

A weakness of the hypothesis of functional myopia is that it must rely on the concept of a spasm due to overuse. To accept that myopia is due to a spasm of the lens or the ciliary muscle requires one to believe in a rather complicated spasm. It is a complicated spasm in that the spasm apparently causes the lens to fail in only one respect – the distance at which it brings light rays to a point. Despite this spasm, all other aspects of the lens apparently remain intact and fully functional. Despite this spasm, light is still accurately focussed at a point (just not at the required point on the retina). Therefore, the spasm only has a very selective effect on the lens. To drawn an analogy, this is like a piano player having a spasm and consequently being unable to play the works of Bach, but having no trouble playing Mozart, Brahms and Listz. This author remains sceptical about the role of lens spasm as a cause of myopia but acknowledges the excellent work done in this area.

Myopia occurs when light does not hit the intended target inside the eye. The hypothesis of functional myopia is based on the assumption that the target inside the eye (the retina) is in the correct position but that the system for aiming at that target (the lens and ciliary muscle) is not functioning properly. If this assumption about the target being in the correct position is a false assumption, then this brings into question whether the system for aiming at that target is not functioning properly. Studies have shown that myopic eyes are longer than normal eyes.[11] This observation about the length of a myopic eye casts serious doubt on whether it can be safely assumed that the target within the eye (the position of the retina) is in the correct position relative to the lens. However, this serious deficiency in the hypothesis of functional myopia can be explained away by assuming that functional myopia precedes and/or accompanies structural myopia (such that the eyeball is longer than a normal eyeball due to excessive growth or stretching by the oblique muscles, as more fully described below).

The hypothesis of functional myopia stresses the importance of the lens in the refractive error characterised as myopia. However, the result of many studies comparing, in terms of refraction, the relative importance of the lens, cornea and axial length, is that the lens is the least important of these variables. Axial length makes the greatest relative contribution to refraction.[12] In a similar vein, Bates made the following observation:
"As has already been noted, the fact that after removal of the lens for cataract the eye often appears to accommodate just as well as it did before is well known. Many of these cases have come under my own observation. … In all these cases the retinoscope [a tool for examining the eye] demonstrated that the apparent act of accommodation was real, being accomplished not by any of the elaborate methods by which this inconvenient phenomenon is commonly explained, but by an accurate adjustment of the focus to the distances concerned."[13]
These observations bring into question the relative importance of the lens in the overall process of refraction and hence weaken the hypothesis of functional myopia.

Structural myopia - elongation through excessive growth or stretching by obliques

From birth through until adulthood, the eyeball grows in length by 30%. In the majority of individuals, eyeball growth occurs in a synchronised fashion – a process referred to as emmetropization. That is, all aspects related to focussing (chiefly the cornea, lens and axial length) remain in step and once clear vision is achieved in early childhood, it is maintained through to adulthood, despite changes in each of these variables. However, in myopes, the eyeball is elongated relative to the dimensions of the cornea and lens. Therefore, the hypothesis of structural myopia has been posited to the effect that excessive growth or stretching of the eyeball by the oblique muscles causes myopia.

Stretching by Cumulative Action of the Oblique Muscles

McCollim has put forward that elongation of the eyeball may occur due to the cumulative effect of the action of certain extraocular muscles, causing the eyeball to bulge or stretch. A pair of obliques (the superior oblique and inferior oblique) are attached to the outside of each eyeball and together they encircle the eyeball like a belt. McCollim notes that reading, with continuous back-and-forth scanning movements combined with a depressed gaze, requires a constant contraction/relaxation of the superior obliques, and proposes that this could compress the eyeball at its equator, causing stretching elsewhere in the eye. Excessive reading could result in the obliques affecting the eyeball's axial length, as tension develops in the belt encircling the eyeball. Given that reading is a near work task and near work is associated with the onset of myopia, McCollim's is an appealing hypothesis as to the cause of myopia. However, other near work tasks such as watching a television at close range do not engage the obliques to a great extent or in the manner described by

McCollim though are still associated with increased myopia.[14] Also, some children become myopic before learning to read (which is partly why eye examinations have been made mandatory in most states in America for children entering kindergarten[15]). Therefore, this author does not accept McCollim's hypothesis as the underlying cause of myopia.

Excessive Growth

Other authors attribute elongation of the eyeball to growth caused by some general adaptive or maladaptive response. Attempts to specify the nature of this response include growth in response to the cumulative effect of increased pressure within the eye resulting from accommodation. Pressure changes within the eyeball have been observed when the eye accommodates for near work.[16] To the date of this paper, the mechanism or source of this change in pressure has remained obscure (but is discussed below).

Relevant to the hypothesis of structural myopia are observations that some people with comparatively short eyeballs are myopic and conversely, some people with comparatively long eyeballs are not myopic. These observations support the view that it is the interrelationship between the variables of the cornea, lens and axial length that are important rather than axial length alone.[17] However, what could be characterised as a major weakness of the hypothesis of structural myopia – that axial length is not always determinative of myopia – can be explained away by attributing observed anomalies to lens effects.

Two different hypotheses put forward to explain why, in a myope's eyeball, other parts of the eyeball (namely the lens and cornea) do not grow in synchrony with axial length are as follows. The first hypothesis is that a point is reached where, due to physical limits based on the shape of a person's skull, the front part of the eyeball (the lens and cornea) cannot grow any more and the only room for growth is elongation back into the socket of the eyeball. This physical limits hypothesis is difficult to test. However, given that the age of onset of myopia varies from childhood through to adulthood and therefore accompanies a whole range of stages of skeletal growth, this author remains sceptical about a hypothesis based on bone structure.

A second hypothesis put forward to explain why other parts of the eyeball (the lens and cornea) do not grow in synchrony with axial length is that the elongation is could be regarded as a positive adaptation to near work. That is, the argument has been made that a longer eyeball is better suited to near work, because a longer eyeball requires less focussing effort on the part of the lens. Put another way, the incoming light rays do not have to be bent as sharply by the lens if the target at the rear of eyeball is further away.

The author of this paper questions the reasoning of this positive adaptation growth hypothesis on two grounds. The first ground on which the reasoning is questioned is that it is based on the assumption that there is always an advantage in having the lens converge light at a more distant point. Any archer will attest to the increase in accuracy afforded by a closer target. Therefore, whilst it is acknowledged that the ciliary muscle must contract in order to make the lens cause light to converge at a closer point, it has not been established how this disadvantage, in terms of muscular effort, of a shorter focal length compares to the advantage, in terms of improved accuracy, afforded by a closer target. Hence the author urges caution in making assumptions in this regard.

The second ground on which the positive adaptation growth hypothesis is questioned is that in a myopic eye, the lens is focussing light rays to a point in front of the retina and therefore any positive adaptation in terms of axial length would be a shortening of the eyeball to meet that point of focus – as opposed to a lengthening of the eyeball, which takes the retina further away from the point of focus. Schmid has summarised relevant studies relating to animals. According to Schmid's summaries, when animals experienced a blurred image on their retina, subsequent compensatory change in shape of the eyeball "was always in the right direction [ie the retina moved towards the focal point rather than away from it], even in the presence of very poor images."[18] The author of this paper submits that there is no clear reason why behaviour of the human eye in this regard should be any different to the observed behaviour in animals – and therefore rejects that a lengthening of the eyeball is a positive adaptation to near work.

Another similar point emerges from studies of artificially induced myopia in animals. Myopia can induced by covering an animal's eyes with frosted glasses, by placing strong minus lenses over the animal's eyes or by restricting the amount of available distance vision through placing the animal in a closely confined environment (eg a small cage). In studies of animals with artificially induced myopia, it has been observed that the eye recovers from a condition of myopia to normal vision if the cover over the eye used to induce myopia is removed. However, no such recovery to normal vision is observed in the animals if the artificially induced myopia is corrected using a minus lens.[19] In humans, the standard treatment for myopia is to correct the condition using a minus lens. Consequently, this author is not surprised by the paucity of reports of recovery from myopia in humans in situations where the ongoing treatment consists of wearing minus lenses.

Regardless of the reason put forward to explain growth in axial length relative to the other elements of the focussing process, the hypothesis of structural myopia does not readily account for the observed dynamic behaviour of the eye. The axial length of the eyeball has been observed to change over a daily cycle not only in chicks, rabbits and monkeys but also in humans.[20] There have been "aberrational changes" in the shape of the eyeball on the scale of seconds, days, weeks and months noted in humans.[21] This dynamic behaviour of eyeball shape does not sit well with a hypothesis which asserts that an eyeball is myopic due to a simple cumulative process of excessive growth or stretching by the oblique muscles.

The ultimate example of dynamic behaviour of the eyeball is the recovery of a myopic eyeball to a normal state. That myopia is due to an eyeball simply growing longer or being stretched by the oblique muscles fails to make sense in light of individuals who have regained normal vision after a period of myopic vision, as this would indicate that the eyeball had somehow grown shorter again. The literature includes documented cases of the recovery of myopic vision to a normal state, both in humans and in animals.[22] Reports of myopia being reversed in animals is not regarded as controversial. Paradoxically, however, the wider vision science community is generally reluctant to accept claims if they relate to recovery from myopia in humans.[23] Instead, recovery in humans is usually attributed to one of four factors:

1. Pseudomyopia – the myopic vision originally experienced was not true myopia (and therefore a return to normal vision does not mean that there has been a reduction of myopia);
2. Coincident presbyopia – the myopia has been balanced by the onset of a different type of refractive error, presbyopia, and the two cancel each other out (and therefore normal vision is regained though there has been no reduction of the underlying myopia);
3. Improved blur interpretation – through practice, the brain learns to improve its interpretation of blurred images (and therefore though a patient over time can read smaller lines on a vision chart, ostensibly indicating an improvement of vision, this improvement is only in the brain and there has been no reduction of myopia);
4. Placebo effect – a myopic individual reports an improvement in vision due to the psychology of the placebo effect based, for example, on a belief in the efficacy of a system of eye exercises (and there has been no actual reduction of myopia).

It is submitted that these four devices (pseudomyopia, coincident presbyopia, improved blur interpretation and placebo effect) have the effect of entrenching the Current Theory, as they may discourage the investigation of the claims of recovered myopes and other observed weaknesses of the Current Theory.

Part 2. The New Theory

The vacuum

Based on the work of Helmholtz and others in the 1800s, the Current Theory rests on the premise that the visual system (consisting of the eyeball, extraocular muscles, optic nerve and relevant parts of the brain) is effectively discrete, with no external influences on the mechanism of accommodation. As outlined in the first part of this paper, the author asserts that there are several weaknesses in the hypotheses that make up the Current Theory.

According to the Current Theory, any effects of the respiratory system are regarded as a confounding variable to be ignored in the analysis of vision. As a result, the direct effect, if any, that the respiratory system has on the visual system has, to this point, been ignored and no account is taken of the respiratory system in the Current Theory regarding myopia or vision in general. For example, Schmid's Myopia Manual (March 2004 edition) is an authoritative compendium of 260 pages summarising the results of over 1000 studies and publications relevant to myopia, yet does not contain any key words relating to the respiratory system such as "breathing" and "sinus". Up to the date of this paper, there has been no specific mechanism proposed as to how the operation of a person's breathing pattern and sinuses may have a direct impact on vision in general and myopia in particular.

A Statement of Scanlan's General Theory of Myopia

The theory put forward in this paper, Scanlan's General Theory of Myopia ("SGTM"), is that the respiratory system directly influences the visual system. More particularly, SGTM holds that the respiratory system applies air pressure to the rear of the eyeballs influencing the shape of the eyeballs and hence influences how clearly we see at different distances (refractive state). Pressure in the respiratory system is established by an individual's breathing pattern, through the action of the diaphragm and other breathing muscles, varies from individual to individual and varies over time. SGTM holds that this pressure is applied to the rear of the eyeballs by action of the paranasal sinuses (commonly referred to as sinuses), which help regulate the pressure.

If the pressure from the respiratory system is normal, the rear of the eyeball is pushed so that the retina is at the position at which light is made to converge by the lens and ciliary muscle. If the pressure from the respiratory system is not normal, the retina is not pushed into the position at which light is made to converge within the eyeball. As a result, the light does not hit the intended target and refractive errors such as myopia are the result.

Increasing the air pressure on the back of the eyeball has the effect of shortening the axial length of the eyeball. Conversely, reducing the pressure on the back of the eyeball has the effect of increasing the axial length of the eyeball.

According to SGTM, myopia arises due to a reduced level of air pressure against the rear of the eyeball, causing a refractive error. SGTM agrees with the current understanding of myopia to the extent that myopia represents light rays converging at a point in front of the retina. However, SGTM diverges from the Current Theory in its explanation of why those light rays converge in front of the retina. SGTM posits that the target is not missed because of light rays being inaccurately aimed by the cornea or by the lens and ciliary muscle. Instead, the target is missed because the target is not where it should be. The target is not where it should be because of a lack of pressure from outside the eyeball. That is, SGTM holds that myopia is directly attributable to a failure of the respiratory system to apply sufficient pressure to the rear of the eyeball in order to keep the retina pushed sufficiently forward to achieve clear distance vision.

SGTM diverges from the functional myopia aspect of the Current Theory because SGTM holds that the lens and ciliary muscle are not at fault in myopia – instead, failure to hit the target is due to movement of the target as opposed to some problem with aiming at the target.

The structural myopia aspect of the Current Theory holds that the increased axial length observed in myopia represents excessive growth of the eyeball due to some factor within the eyeball or due to the cumulative effect of the operation of the oblique muscles. By contrast, SGTM holds that the increased axial length observed in myopia is due to a dynamic effect caused by the eyeball rebounding against reduced pressure applied to the rear of the eyeball.

SGTM holds that pressure applied to the rear of the eyeballs causes changes to the axial length of the eyeball. By changing the axial length of the eyeball, the respiratory system has a direct influence on the task of accommodation.

SGTM holds that the main role of blinking is to re-set the focussing mechanism of the lens and ciliary muscle in response to the changes in axial length brought about by changing pressure from the respiratory system. According to SGTM, the lens and ciliary muscle are a slave to axial length and at each blink must adjust to the axial length change which prompted the blink.

SGTM holds that myopia is a symptom of a poor breathing pattern and that poor breathing is the until now hidden factor that directly causes myopia. As a result, treatment of myopia should be directed towards the respiratory system. Any treatment of the visual system should be minimal, short term and not impose changes on the mechanisms of the visual system.

SGTM holds that the pressure in the respiratory system necessary to sustain respiration is less than the pressure in the respiratory system necessary to maintain clear distance vision. For this reason, pressure in the respiratory system can fall below the level necessary to sustain clear distance vision without noticeably impacting upon the other tasks of the respiratory system, including the regulation of oxygen and carbon dioxide in the body.

According to SGTM, the task of near work requires that pressure in the respiratory system pressing on the back of the eyeball be reduced compared to the pressure necessary for distance work. As a result, when a person is engaged in near work, a breathing pattern appropriate for near work is employed. According to SGTM, a consequence of excessive near work is to re-train a person's breathing pattern so that the breathing pattern appropriate for near work becomes the norm. As a consequence of this change in breathing pattern, the body's ability to generate the higher pressure in the respiratory system necessary for distance work is reduced and this is manifested as myopia.

When a person presents with the symptoms of myopia (generally a reduced ability to see into the distance), the standard current practice is to prescribe a minus lens. The optical effect of the minus lens (in glasses, contact lenses or achieved surgically through laser techniques applied to the cornea) is to turn distance work into near work. Consequently, according to SGTM, the effect of wearing the minus lens (compared to wearing no lens or a plus lens) is to encourage the person to adopt a breathing pattern appropriate for near work, even when viewing objects in the distance. Therefore, by optically increasing the exposure to near work, the effect of wearing the minus lens is likely to hasten or entrench a person's adoption of a change in breathing pattern, so that the breathing pattern appropriate for near work becomes the norm. As a consequence of this change in breathing pattern, the body's ability to generate the higher pressure in the respiratory system necessary for distance work is reduced.

SGTM explains some important but previously unknown or misunderstood aspects of the visual system (including the genesis of myopia, the mechanism of

accommodation and the role of blinking) and aspects of the respiratory system (including the role of the sinuses and implications of breathing pattern). SGTM brings new understanding to the fields of vision science and respiration science and has major practical implications such as for the treatment of myopia.

Part 3. The Evidence

SGTM is a simple, novel theory. The core of SGTM is that the respiratory system applies air pressure to the rear of the eyeballs influencing the shape of the eyeballs and hence influencing how clearly we see at different distances. SGTM is in stark contrast to the Current Theory. If SGTM is correct, then it follows that many observations concerning vision, myopia, blinking, the sinuses and the respiratory system should support SGTM but be in conflict with the Current Theory or not be readily explained by the Current Theory. It is submitted that the diverse range of observations considered below can all be interpreted in accordance with SGTM. As with any new theory, the author invites further investigation to confirm each aspect of SGTM.

When we sneeze, we close our eyes

When a person sneezes, the reflex response is for that person to close his or her eyes. The author asserts that the reflex response of eyelids closing upon sneezing indicates that pressure from the respiratory system pushes against the back of the eyeballs. The reflex response ensures that when this pressure from the respiratory system is excessive, such as during a sneezing event, the eyeballs are braced by the eyelids so that they are not pushed forward, potentially right out of their sockets.

If the respiratory system and visual system are not connected in the manner described by SGTM, it is difficult to find a compelling reason why the eyes must be closed at the point of sneezing. Though material is ejected from the mouth and nose at high speed during sneezing, the position of these apertures means that such material is ejected away from the direction of the eyes. Current Theory recognises that because the tear ducts drain into the nasal passages and then into throat, a person may, for example, be able to taste eyedrops which have been placed into their eyes.[24] However, beyond this observation concerning the tear ducts, the Current Theory does not appear to address this linkage between the visual system and the respiratory system illustrated by sneezing.

O*ur eyes may prompt a sneeze*

If the respiratory system influences the visual system, as posited by SGTM, then we may expect to be able to observe some evidence of feedback from the visual system to the respiratory system. It has been noted that in some people, the action of rubbing the inner corner of the eye can trigger a reflex sneezing response.[25] The author suggests that these observations are illustrative of a connection between the visual system and the respiratory system. However, it is submitted that the strongest evidence of the visual system influencing the respiratory system is the photic sneeze reflex.

Approximately 20% of people exhibit the photic sneeze reflex. This describes the situation that occurs when a person's eyes become adapted to dark conditions, such as in a movie theatre, and then, by reflex action, he or she sneezes one or more times when suddenly exposed to bright light. Hence the visual system appears to have a direct effect on the respiratory system.

The chest muscles and diaphragm are the primary muscles of breathing and sneezing. The fifth cranial nerve, also known as the trigeminal nerve, is responsible for triggering these muscles to generate a sneeze. The photic sneeze reflex has prompted investigation into the trigeminal nerve. Research on the trigeminal nerve nucleus suggests that at least some people have an association between this nerve and the nerve that transmits visual impulses to the brain. Whilst this might be characterised in current neurological research as "leakage" from one nerve pathway (a visual pathway) to another (a respiratory pathway),[26] it is submitted that SGTM explains why the nerves of the visual system and respiratory system interact – this is because the respiratory system influences the visual system.

Blink rate is related to breathing rate

The major role of blinking, according to the Current Theory, may be to re-wet the eyeball with tear fluid.[27] Clearly, the outermost layers of the eye are very complex and extended periods of staring rather than blinking does lead to the surface of the eyes drying out. However, the author of this paper invites further critical evaluation of whether or not re-wetting the eye is the major role of blinking. Secondary roles of blinking, such as to clear the eye of specific pieces of debris, are beyond the scope of this paper, which instead considers only what is known as spontaneous blink activity.

If the major role of blinking is to re-wet the eyes, a reasonable prediction would be that a person's blink rate would generally remain constant, except when there are changes in humidity or other factors affecting evaporation rates. However, many studies have shown that blink rates vary depending upon what the person is doing at the time. For example, Tsubota and Nakamori found that while viewing a computer screen, the average blink rate was once every 8.5 seconds, while reading a book the average blink rate was once every 6 seconds and while doing neither of these activities the blink rate was once every 3 seconds.[28] Current Theory continues to debate whether some as yet unknown central control mechanism exists (based for example on neurological and/or biomechanical factors) to make sense of the observed blink rate relationships.[29]

If the eyes dry out so quickly that, when not reading, it is necessary to re-wet them every 3 seconds, it is difficult to understand why the blink rate drops by half when a person starts reading. The answer favoured by most vision scientists is that humans are not well-adapted to doing near work, especially if concentration is involved – that the eye lets us down by neglecting its re-wetting role and instead keeps eyelids out of the way so that the task of reading can be accomplished. However, before paint manufacturers scramble to unlock the secrets of a wet surface that apparently dries out so quickly, the author recommends that another theory, SGTM, be considered as an explanation of why we blink so frequently at some times and not so frequently at other times. This explanation is set out in the following paragraphs.

Rather than being rigid and inflexible, the eyeball has the consistency of a gelatinous ball. Therefore, provided sufficient pressure is applied to such a ball, the shape of the ball will change, such as its observed length in a given axis.

The length of the eyeball (axial length) is one of three key variables in accommodation (the focussing process). The other two variables are the lens and the cornea. Therefore, for an object to remain in clear focus, a change in axial length must be accompanied by a change in the lens and/or the cornea.

Each time a person blinks, there is a momentary (usually 100 to 150 milliseconds) break in the light entering the eye.[30] When the eye opens at the conclusion of a blink, the lens can again focus on the object being viewed. Therefore, a blink gives the lens an opportunity to refocus.

It is submitted that in each of the three paragraphs above, a simple, logical conclusion is reached. The combination of these three conclusions forms part of SGTM and explains why we blink. SGTM says that pressure is applied to the rear of the eyeball by the respiratory system. As a result of variation in this pressure, there will be a change in the eye's axial length. For an object to remain in clear focus, a change in axial length must be accompanied by a change in the lens and/or the cornea. The action of a blink allows a re-setting of the lens in response to this change in axial length and as a consequence, clear focus is maintained.

If this explanation provided by SGTM is correct, we would expect to observe a relationship between breathing rate (a key factor in the respiratory system) and blinking. Hence, we would expect to see increased rates of blinking when a person is angry, excited or anxious. Conversely, we would expect to see lower rates of blinking when a person is relaxed and not talking. Studies show that this indeed is the case.[31] Whilst it is possible to formulate alternative hypotheses explaining each of these observed blink rate relationships, the author submits that the observations are all in keeping with the simple explanation provided by SGTM. Therefore, the author suggests that these observations may be illustrative of a connection between the visual system and the respiratory system in the manner described by SGTM and also serve to support SGTM's explanation of the role of blinking and the direct impact of the respiratory system on the process of accommodation.

Where are the sinuses and what do they do?

It is submitted that current understanding of the sinuses is strong on the question of where they are located, but weak on the question of what they do. Further, it is submitted that the location of the sinuses may give a clue as to their role.

The sinuses (more correctly the paranasal sinuses) consist of four pairs of chambers in the skull and face region. The sphenoid sinuses are located in the middle of the skull. The maxilliary sinuses are under the eyes. The frontal sinuses are over the eyes. The ethmoid sinuses are between the eyes and the nose. Put another way, the sinuses are located around the eyes.

Forming part of the respiratory system, the sinuses have basically rigid walls with relatively small ostia for gas exchange and mucus transport.[32] Ostia, which can be thought of as holes, are constricted openings in the sinus walls and they have a higher percentage of cilia (hair-like structures) than the surrounding mucosa.

The sinuses may have one or more roles. Various roles have been suggested for these structures and probably the most commonly put forward is that they serve to help warm and humidify air before it reaches the lungs. However, this role seems difficult to reconcile with common understanding. This author remains to be convinced that inhaled air first passes through, for example, the frontal sinuses in the forehead, before leaking out of tiny holes (the ostia), then making its way to the lungs. Though this speculation is not determinative of the matter, it appears that the sinuses must have some other role.

Other possible roles have been suggested for the sinuses: that they increase the resonance of the voice, serve to make the front of the skull lighter, provide a protective buffer against blows to the front of the face or represent a vestigial remnant of a structure evolved for an increased sense of smell. However, none of these possible roles for the sinuses have been embraced as the main role of these chambers.[33]

Given the proximity of the sinuses to the eyes, it seems reasonable to consider whether the sinuses might play some role in relation to vision. In this regard, SGTM holds that pressure from the respiratory system is applied to the rear of the eyeballs by action of the sinuses, which help regulate this air pressure. Pressure in the respiratory system is established by an individual's breathing pattern, through the action of the diaphragm and other breathing muscles. SGTM holds that the pressure applied to the rear of the eyeballs influences the shape of the eyeballs and hence influences how clearly we see at different distances.

If SGTM is correct, we would expect to be able to observe a connection between the sinuses and visual system and vice versa.

Connection between the sinuses and visual system

The impact of sinus surgery gives an indication of a connection between the sinuses and visual system. Several symptoms may be observed following surgery on the sinuses. One of these is blurred vision.[34] Such a loss of vision will often be attributed to the surgery inadvertently causing damage to the optic nerve, which carries information from the eye to the brain. It has been observed that the fibres of the optic nerve are covered with the same kind of myelin as the central nervous system (as opposed to the myelin covering the peripheral nervous system) and that as a consequence these fibres are incapable of regeneration.[35] Therefore damage to the optic nerve seems like a very plausible explanation for a reduction in quality of vision following sinus surgery. (Patients reporting blurred vision after sinus surgery are duly referred to opticians or opthalmologists to determine whether glasses should be prescribed.) However, whilst accepting that damage to the optic nerve will have an adverse impact on vision, the author submits that this very plausible explanation (the delicate nature of the optic nerve) may have obscured a connection between the sinuses and visual system as described by SGTM. That is, the author speculates that surgery on the sinuses may have an adverse impact on vision though no damage has been inflicted on the optic nerve.

The impact that the sinuses may have on the visual system is also illustrated by the observation that medical conditions affecting the sinuses, such as invasive fungal sinusitis[36] and sinus thrombosis[37], are sometimes accompanied by a deterioration of vision. However, as noted above, this deterioration will often be attributed to some co-incident effect on the optic nerve.

Connection between the visual system and the sinuses

If it is observed that the visual system can have an influence on the sinuses, this lends support to SGTM. It has been noted that "eye problems" cause headaches and that the discomfort is usually just above the eyes.[38] When glasses with a new prescription are worn for the first time, this change in the visual system is sometimes accompanied by a headache.[39]

If one accepts that the visual system is effectively discrete, consisting only of the eyeball, extraocular muscles, optic nerve and relevant parts of the brain, it is difficult to explain headaches in the forehead induced by a change in the visual system. The attachments of the extraocular muscles are confined to the orbit of the eye. The part of the brain generally accepted as being responsible for vision is towards the back of the skull.[40] Therefore, if it is accepted that the visual system is effectively discrete, to explain a headache in the forehead requires reliance on a general "muscle-tension" model that happens to concentrate stress in the forehead.[41] On the other hand, SGTM readily accounts for a headache in the forehead induced by a new prescription. According to SGTM, the visual system and the sinuses influence one another: the pain in the forehead is pain in the sinuses, which are adjusting to the change imposed on the visual system by the wearing of the new glasses.

A similar observation emerges from a survey of 838 patients undergoing a course of vision therapy. When asked to name what changes they had observed since commencing the course, 162 patients mentioned having fewer headaches.[42] If it is assumed that many of the headaches experienced before the course of vision therapy represented pain in the sinuses, then this observation is consistent with SGTM to the extent that it shows that the visual system has an influence on the sinuses.

On the basis of the observations made above in relation to the connection between the sinuses and vision, this author therefore concludes that there is evidence that the sinuses play a role in vision, in accordance with SGTM.

Observed changes in the length of the eyeball during accommodation

According to SGTM, the task of near work requires that pressure in the respiratory system pressing on the back of the eyeball be reduced compared to the pressure necessary for distance work. This reduction of pressure on the back of the eyeball has the effect of increasing the axial length of the eyeball. If SGTM is correct, we would expect to see a lengthening of the eyeball when the eye is accommodating for near work.

Partial coherence interferometry can be used to measure the length of the eyeball. Observations made using this method have shown that the eyeball lengthens when accommodating for near work.[43] Therefore, these observations are in full agreement with SGTM.

Current Theory has traditionally been based on a model where the ciliary muscle and lens are primarily responsible for focussing light and there is no variation in eyeball axial length. Hence Current Theory does not readily account for observations of an increase in axial length during accommodation. However, Drexler et als have put forward the following possible explanation: lengthening of the eyeball during accommodation is achieved "…by the accommodation-induced contraction of the ciliary muscle, which results in forward and inward pulling of the choroids [the middle layer of the wall of the eyeball], thus decreasing the circumference of the sclera [the outer layer of the wall of the eyeball], and leads to an elongation of the axial eye length."[44] Hence, according to Drexler et als' hypothesis, when the ciliary muscle contracts, it not only achieves a change in shape of the lens but, by pulling the wall of the eyeball inwards, also achieves a change in shape (a lengthening) of the eyeball.

Drexler et als' hypothesis stays within the constraints of the model that the visual system (consisting of the eyeball, extraocular muscles, optic nerve and relevant parts of the brain) is effectively discrete, with no external influences on the mechanism of accommodation. There is no doubt that the ciliary muscle is a highly specialised muscle, constantly helping to accurately bring objects into focus. However, the author questions the Drexler et als' hypothesis on two grounds.

In conventional anatomy, when describing a muscle, the muscle's points of attachment to bones or other muscles are designated either as a point of origin or a point of insertion. The point of origin is the point of attachment to the bone (or muscle) to which the muscle being described is anchored. The point of insertion is the point of attachment to the bone (or muscle) which the muscle being described moves.[45] In order to fit the constraints of a model of a discrete visual system, the Drexler et als' hypothesis asserts that a single muscle (the ciliary muscle) changes the shape of two different parts of the eye (the lens and the wall of the eyeball) at the same time. In the Drexler et als' hypothesis (and as a generally accepted principle in vision science), the attachment of the ciliary muscle to the wall of the eyeball is a point of origin, because it anchors the ciliary muscle as the ciliary muscle moves the lens. However, in the Drexler et als' hypothesis, the attachment of the ciliary muscle to the wall of the eyeball is also a point of insertion, because the ciliary muscle moves the wall of the eyeball, presumably as the ciliary muscle is being anchored by the lens. Given that the Drexler et als hypothesis appears to describe a novel situation where a single attachment is both a point of origin and a point of insertion, which defies a basic principle of anatomical nomenclature, this author remains sceptical as to its validity.

The second ground on which this author questions the Drexler et als' hypothesis is based on an observation about myopia. As noted earlier in this paper, myopia is condition where light is made to converge in front of the retina. Hence, there is a mismatch between where the lens and ciliary muscle cause the light to be focussed and where the retina is located (the location of the retina depends on the axial length of the eyeball). It is submitted that it is more plausible that this mismatch occurs because two systems are involved - that is, the ciliary muscle controlling where the light converges and the respiratory system controlling the location of the retina – compared to a mismatch arising where a single muscle controls both where the light converges and the location of the retina.

Drawing these arguments together, the observed changes in the length of the eyeball during accommodation are in full agreement with SGTM as noted above. These observations can also be made to fit the model of a discrete visual system if it is accepted that Drexler et als' hypothesis is correct. However, this author questions the Drexler et als' hypothesis on two grounds: first, the hypothesis appears to describe a novel situation where a single muscle attachment is both a point of origin and a point of insertion and second, the mismatch observed in myopia is more plausibly explained by a model in which one system controls where the light converges and a different system controls the location of the retina, as opposed to a model in which these two variables are under the control of a single muscle.

Observed changes in the length of the eyeball over different time scales

Changes in the length of the eyeball are observed when the eye accommodates for near work. However, as noted in the first part of this paper, "aberrational changes" have been observed in the shape of the eyeball on the scale of seconds, days, weeks and months.[46] It is submitted that if the respiratory system applies air pressure to the rear of the eyeballs, as posited by SGTM, this readily explains why the shape of the human eyeball changes on the scale of seconds, days, weeks and months. These changes simply reflect a person's breathing pattern and fluctuations in pressure in the respiratory pressure. On the other hand, the Current Theory does not readily account for these changes in shape and in the words of Hofer et als, "The origin of these measured fluctuations is not known …".[47]

Observations about breathing

A person breathes at least 20,000 times per day and this process is under both conscious and unconscious control. To date, the main recognised roles of the respiratory system are to supply the body with sufficient oxygen, to remove carbon dioxide and to maintain a constant pH in the bloodstream.[48] Breathing patterns reflect many variables. These variables include the extent to which breathing engages the diaphragm and chest muscles, the relative use of the nose and mouth, and timing of breaths. Consequently, breathing patterns differ between individuals and differ for the same individual over time.

Variation has been observed between individuals in terms of pressure within the respiratory system. Part of this variation is attributed, for example, to the degree to which some individuals breathe through their nose and others through their mouth.

Nose breathing facilitates 10 to 20% more oxygen diffusion in the lungs due to the creation of a pressure difference between the lungs and the atmosphere. On the other hand, breathing primarily through the mouth does not create this advantageous pressure difference.[49]

For a person at rest, the driving force behind the rate of respiration is carbon dioxide. In this regard, Stark and Stark note the following:
"When a person is resting, the respiratory centre in the brain keeps this tension [carbon dioxide pressure in the arteries of 40 mm Hg] steady by maintaining breathing between four and six litres of air each minute. When the carbon dioxide pressure falls below 40 mm Hg then there is no stimulation of breathing and a moderate rhythmic pace is maintained until the pressure rises to 40 mm Hg again (Tortora 1984). But even a tiny increase in carbon dioxide tension stimulates breathing. For example if the tension rises by one mm Hg, an extra three litres of air is breathed each minute to ride the body of this excess (Kapit 2001)."[50]
By contrast, the position in relation to oxygen is quite different:
"Approximately one hundred times less oxygen (1.55 litres) is stored in the body than carbon dioxide (120 litres), yet oxygen has to drop by over one third, from the standard 104 mm Hg to approximately 60 mm Hg, before breathing is stimulated to restore normal pressure (Lumb 2000). ***This indicates that survival is possible with considerably less oxygen than is ordinarily provided by breathing***."[51] [Emphasis added.]

According to Peper and Tibbetts, "Breath patterns are covertly conditioned to common or habitual activities. These conditioned patterns include breath holding when the telephone rings, shallow thoracic breathing when entering data at the computer keyboard, and gasping during speech. … Hence, the dysfunctional breathing patterns have become part of the physiological response during task performance."[52] More generally, stress has been noted as a factor associated with abnormal breathing patterns. A strong connection has also been observed between sufferers of asthma and abnormal breathing patterns (not just at the point of the asthma attack itself).[53]

Schmid notes that when exposed to the same environment, the same tasks and the same nutrition, some people become myopic and some will not. In relation to observations about myopia, he also refers to the possibility of some connecting logic that is yet to be revealed.[54] To the casual observer, differences in breathing pattern are effectively invisible. Hence the difference between a person with a normal breathing pattern and what could be called an abnormal breathing pattern may go unnoticed.[55] This author submits that a theory based on the respiratory system supplies the logic connecting observations about myopia.

SGTM holds that the pressure in the respiratory system necessary to sustain respiration is less than the pressure in the respiratory system necessary to maintain clear distance vision. For this reason, pressure in the respiratory system can fall below the level necessary to sustain clear distance vision without noticeably impacting upon the other tasks of the respiratory system, including the regulation of oxygen and carbon dioxide in the body.

According to SGTM, the task of near work requires that pressure in the respiratory system pressing on the back of the eyeball be reduced compared to the pressure necessary for distance work. As a result, when a person is engaged in near work, a breathing pattern appropriate for near work is employed. According to SGTM, a consequence of excessive near work is to re-train a person's breathing pattern so that the breathing pattern appropriate for near work becomes the norm. As a consequence of this change in breathing pattern, the body's ability to generate the higher pressure in the respiratory system necessary for distance work is reduced and this is manifested as myopia.

If myopia is a symptom of an abnormal breathing pattern and abnormal breathing is the (until now) hidden factor that directly causes myopia, as posited by SGTM, we would expect to observe a connection between myopia and other factors associated with breathing pattern, such as general stress and asthma.

Stress and myopia

There are numerous different definitions of stress. However, the most commonly accepted definition is that stress is a condition or feeling experienced when a person perceives that demands exceed the personal and social resources the individual is able to mobilize.[56] The discussion that follows is based on the premise that stress is a factor associated with abnormal breathing patterns.

A connection has been noted between myopia and stress.[57] Schmid summarises several relevant studies in this regard. Three of these are of particular interest.

According to Schmid, the finding of a study by Goldschmidt[58] was as follows: "Workers checking merchandise for faults (requiring high and sustained concentration) became myopic while colleagues doing other near work were unaffected." [Emphasis in original removed.][59] The author of this paper speculates that near work requiring high and sustained concentration is an activity more likely to have an impact upon breathing pattern than other near work. If this speculation is correct, Goldschmidt's study may demonstrate that it is not simply the act of doing near work itself that causes myopia but that myopia arises due to an abnormal breathing pattern associated with near work. SGTM posits that the onset of myopia is a symptom of an abnormal breathing.

Schmid also refers to the work of Liberman, who reports that the first prescription of corrective lenses frequently occurs at a time of personal stress.[60] If it is accepted that stress is likely to impact upon breathing pattern, then Liberman's observation suggests a connection between myopia and an abnormal breathing pattern. Again, this interpretation is consistent with SGTM.

Schmidt cites a study by Schultz-Zehden as reporting that feelings of stress and anxiety are able to influence myopia.[61] Again, if stress and anxiety affect breathing pattern, then Schultz-Zehen's study assists in demonstrating a link between an abnormal breathing pattern and myopia.

The author of this paper acknowledges the possibility that the effect of stress which may lead is myopia is not necessarily an effect on breathing pattern. Instead, the relevant effect of stress may be that it leads to a spasm of the ciliary muscle or some other dysfunction.

Asthma and myopia

Like myopia, there has been a significant increase in the past twenty years in the incidence of asthma. It has been shown that asthma is related to an abnormal breathing pattern, not only at the time of an asthma attack but also at times when no symptoms are present.[62] It has also been shown that by re-education of an asthmatic's breathing pattern, the symptoms of asthma can be significantly reduced. The relevant study, a blinded randomised controlled trial, referred to in Stark and Stark, showed a 49% average reduction in asthma preventer medication use in the test group after three months compared to unchanged preventer use in the control group; similarly, the test group showed a 96% reduction in the use of asthma reliever medication after three months compared to a 5% average reduction in the control group.[63]

Current Theory ascribes no role to breathing pattern in the onset of myopia. By contrast, SGTM holds that myopia is caused by and is a symptom of an abnormal breathing pattern. If SGTM is correct, then we should observe that myopes have an abnormal breathing pattern and have other symptoms of an abnormal breathing pattern.

Storfer found that myopes were nearly twice as likely as non-myopes to have severe or multiple allergies including asthma.[64] Schmid cites a study by Dolezalova and Mottlava that included data about myopia and asthma. According to Schmid, the Dolezalova and Mott study showed that: "Myopia, and asthma and other allergies, were substantially higher among extremely mathematically and/or verbally excellent students."[65] It is submitted that the findings of Dolezalova and Mottlava's study are consistent with the conclusion that there is an association between myopia and asthma and that this is a result of both conditions arising from abnormal breathing patterns. This association between myopia and asthma is in accordance with SGTM but is not explained by the Current Theory. Further investigation is required to conclusively demonstrate an association between myopia and asthma.

Pregnancy and myopia

One study has shown a shift towards or increase in myopia during pregnancy, followed after birth by a reversal of this shift or increase.[66] It is submitted that the Current Theory does not readily explain this observation.

The author notes that a mother's breathing pattern may change during the course of a pregnancy and also change again after giving birth. For example, it has been observed that chronic hyperventilation (that is, an abnormal breathing pattern over a long period) may occur during the course of pregnancy but that symptoms usually disappear of their own accord after birth.[67] Therefore, it is submitted that the study concerning myopia and pregnancy may illustrate a connection between myopia and breathing pattern (and therefore support SGTM).

Natural vision improvement

Natural vision improvement is a controversial area, yet to be fully embraced by the wider vision science community. Natural vision improvement techniques are many and varied, though common themes do emerge. Roy, Kaplan, Grunwald and Anghart are four examples of authors who claim to have experienced moderate to high levels of myopia and subsequently improved their vision using natural vision improvement techniques.[68] For the purposes of open-minded scientific enquiry, in this paper it will be assumed that these four people have experienced at least a reduction of their myopia.

The specific mechanism by which the respiratory system influences the visual system has not been elucidated until the date of this paper. However, as a key factor in myopia reduction, Roy, Kaplan, Grunwald and Anghart each recommend relaxation and/or relaxed breathing (as well as reducing the strength of or where possible removing corrective lenses). To the extent that these individuals, and other users of natural vision improvement techniques, re-train their breathing pattern and achieve improvements in vision, it is submitted that these results are supportive of SGTM.

Altering dental occlusion induces fluctuations in vision

One study reports that dental occlusion appliances, examples of which include teeth straightening devices, can induce fluctuations in vision. This observation is difficult to explain by reference to the Current Theory. However, if it is assumed that these applicances alter the airflow through the mouth and consequently the wearer's breathing pattern, then the observed impact on vision is readily seen as an example of the respiratory system influencing the visual system. As such, this observation concerning dental occlusion devices can be interpreted as supporting SGTM.

Medical strength hyperbaric chambers

Hyperbaric chambers are used for a diverse range of medical purposes, including to accelerate recovery from sports injury related trauma, as well as for more cosmetic purposes under the headings of general health, beauty and wellness. Treatment in a hyperbaric chamber involves exposing a person to pressures in excess of normal atmospheric pressure. Medical strength hyperbaric chambers usually apply pressure to a patient in the range from 2.5 to 6 times normal atmospheric pressure, though mild hyperbaric chambers offering cosmetic benefits operate at a maximum pressure of only 1.3 times normal atmospheric pressure.[69]

In contrast to SGTM, the Current Theory does not ascribe any role to pressure on the back of the eyeball influencing its refractive state. As a result, the observation that treatment in a medical strength hyperbaric chamber sometimes induces myopia for a short period (in the order of two to four weeks)[70] is difficult to explain in terms of the Current Theory but is readily found to be consistent with SGTM.

Given that the Current Theory emphasises the importance of the lens in the focussing process, it is not surprising that it has been suggested that the short-term myopia arising as a side-effect of treatment in a medical strength hyperbaric chamber is attributable to swelling of the lens.[71] However, this may be conjecture based on the reasoning that a thickening of the lens must be involved, as this would cause greater refraction and therefore explain a myopic outcome. This author remains sceptical of the lens swelling explanation and is unaware of any other particular body parts that swell for two to four weeks following hyperbaric treatment. On the contrary, hyperbaric treatment is often observed to reduce swelling in damaged tissues.[72]

In light of SGTM, the author ventures that this short-term myopia as an occasional side-effect of medical strength hyperbaric treatment is due to the treatment disturbing the relationship between the pressure pressing against the back of the eyeball and relative pressures within the sinus chambers and remainder of the respiratory system.

The extraocular muscles

The extraocular muscles in humans consist of three pairs of muscles surrounding each eye. According to the Current Theory, the primary function of the two pairs of rectus muscles is to control the eye's movements from left to right and up and down, whilst rotation of the eyes inward and outward is achieved by the pair of oblique muscles.[73]

In a review of the literature on the distinctive characteristics of extraocular muscles, Fischer et als note that morphologically, physiologically, or biochemically defined fibre types in extraocular muscles do not correspond to those in other skeletal muscles. Fischer els also note that the combination of fast contractile properties, high oxidative capacity, and high fatigue resistance is unusual among skeletal muscles and further emphasizes the complexity of these muscles.[74]

Some authors note the time-honoured observation that extraocular muscles in humans are 100 times stronger than they need to be to move the eyes.[75] To make an assessment of how strong extraocular muscles "need to be" requires an assessment of their role. The Current Theory posits that the role of the extraocular muscles is merely to point the eyeballs in the right direction, albeit with lightning speed and pin-point accuracy. The theory put forward by this paper is that the eyeballs are under pressure from the respiratory system pushing them forward. As a result, SGTM asserts that, in light of the need to resist the pressure exerted through the sinuses by the respiratory system, the extraocular muscles are not 100 times stronger than they need to be.

Two aspects that make the human visual system relatively complex compared to the visual system of many other species are binocular vision and the presence of a fovea. With binocular vision, teaming of the eyes is required so that each eye points at exactly the same object. In this teaming exercise, great accuracy is essential so as to enable the brain to make accurate judgments of depth (how far away an object is) and to enable the brain to fuse together the separate images from the two eyes. The presence of a fovea also adds complexity to the human visual system. The fovea, and particularly a 0.2 mm wide pit at the centre of the fovea, is the most sensitive part of the retina, containing a disproportionately high number of visual sensory structures. The fovea is responsible for sharp central vision, being critical to any activity where visual detail is of primary importance, such as reading, driving or watching television.[76] Foveal vision requires that eyeball movement be both rapid and accurate.[77] Unlike humans, many other species of mammals, including rodents, lack binocularity and foveal vision.

Binocularity and foveal vision are two reasons why the movement of human eyes may require highly specialised muscles. The distinctive characteristics of human extraocular muscles are described above. If these distinctive characteristics are largely a consequence of the demands of binocularity and foveal vision (speed and accuracy), one might reasonably expect the extraocular muscles in mammals with more simple visual systems to exhibit somewhat different characteristics. In this regard, the question arises as to whether or not the extraocular muscles of rodents, for example, reflect the absence of the special demands of binocularity and foveal vision and are therefore distinctly different to the extraocular muscles of humans. On this point, the author asserts that the findings of Fischer et als set out below may be relevant.

Fischer et als sought to define the typical pattern of gene expression (or "allotype") in human extraocular muscles. Fischer et als' findings include the following comments:
"Our current study [of human extraocular muscle allotype] showed a high degree of concordance with profiling studies that defined the rodent EOM [extraocular muscle] allotype. The concordance was somewhat surprising, since interspecies differences of the visual system between rodents and humans are quite pronounced; rodents have a simpler visual system lacking a fovea and do not use binocular vision."[78]

If human extraocular muscles and rodent extraocular muscles are so similar, yet they form part of visual systems that are so different, then perhaps the special features of extraocular muscles are not solely a consequence of their role in humans to move the eyeballs very quickly and very accurately. Instead, some other role, common to both extraocular muscles in humans and extraocular muscles in rodents, may explain the surprising similarity.

Some scientists studying human sinus disorders have used both rats and mice as a model, on the basis of similarity between the sinuses of humans and sinuses of rodents.[79] The author speculates that the close similarity between extraocular muscles in humans and rodents cannot be explained by a comparison of visual systems but instead is directly related to the similarity between the sinuses of humans and sinuses of rodents. SGTM posits that the pressure of the respiratory system pressing on the back of the eyeballs is regulated by the sinuses. If sinuses play this role in both humans and rodents, we would expect humans and rodents to have similar extraocular muscles to resist this pressure, which is in line with Fischer et als' observations. To that extent, combining the findings of Fischer et als in physiological genomics together with the observed similarity between the sinuses of humans and rodents can be interpreted as supporting SGTM.

4. Implications of the New Theory

It is submitted that in the form of SGTM, this paper supplies the underlying logic that ties together the observations about myopia as well as other observations more generally concerning vision and the respiratory system. The following discussion of the implications of SGTM assumes that SGTM is correct, which is an assumption that many will quite rightly only very cautiously accept. If anything, SGTM should at least serve to invigorate the debate in this field.

The implications for treatment of myopia

Put succinctly, myopia is a case of light rays in the eye not hitting their intended target. Orthodox treatment, based on the Current Theory, is to adjust the eye's aiming mechanism, by the use of laser surgery or minus lenses in the form of glasses or contacts. SGTM indicates that a more appropriate long term treatment may be to adjust the target back to its normal place through addressing the myope's breathing pattern.

To this point, the standard tools of the vision professional have been the minus lens and the plus lens. The optical effect of a plus lens is to push objects further away, turning near work into distance work. Conversely, the optical effect of a minus lens is to bring objects closer, turning distance work into near work. For people who cannot see objects clearly in the distance, the minus lens is an obvious quick solution because it effectively brings distant objects closer so that they are within the range of clear vision. However, vision professionals dealing with the public have always been faced with a difficult decision in this regard. Long recognising that myopia is somehow associated with excessive near work, vision professionals have been in an unenviable position: if they prescribe a minus lens to make the viewing of distant objects easier, as demanded by the public, the risk is run that a patient's myopia may increase due to the effective increase in the amount of near work brought about by use of the minus lens.

The public demand for a quick fix has been sufficient to de-rail attempts to prescribe a plus lens as part of a strategy in dealing with myopia. By careful use of a plus lens for reading, it may be possible to turn that near work into more distant work, and therefore reduce one's overall exposure to near work – in a bid to stop whatever it is about near work that causes myopia. However, this approach has not gained widespread acceptance.[80]

The position has changed, however, in light of the new understanding brought about by SGTM. Now that we know that an abnormal breathing pattern is the cause of most myopia, vision professionals and members of the public alike will have new tools to address this issue. More than ever, workers will have an excuse to periodically look out the window into the distance and practice doing nothing but breathing. Laser surgery and minus lenses will remain as options for the treatment of myopia. However, with protocols for normalising breathing patterns specifically for vision purposes being developed by this author, vision professionals will now have new options at their disposal for treating myopic patients. This step forward parallels the use of breathing normalisation protocols directed towards asthmatics and those with high blood pressure, which have been shown in clinical trials to be successful in reducing the severity of symptoms of those conditions.[81] As always, the vision professional's expertise and judgment will help inform the patient as to which treatment options are the most appropriate, and this of course will depend on many factors, such as the motivation level of the patient and the demands of the patient's particular physical condition.

Other implications of the new theory

Beyond the treatment of myopia, SGTM opens up new questions for researchers dealing with vision more generally, including in the areas of accommodation and blinking.

SGTM also offers new insights into the operation of the respiratory system. In particular, SGTM may spark new research into the diagnosis and treatment of abnormal breathing patterns, the role of the sinuses and the interaction between the respiratory system and the visual system.

CONCLUSIONS

This paper introduces Scanlan's General Theory of Myopia.

ACKNOWLEDGMENTS

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REFERENCES

The references for this paper are set out at the end of the figures. The figures are set out on the following pages.

Paul Scanlan, 13 January 2006.

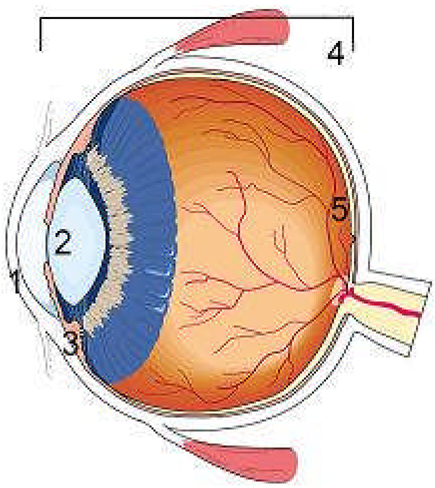

Figure 1. The basic determinants of vision ***within*** the eyeball. According to Scanlan's General Theory of Myopia, the respiratory system applies pressure to the rear of the eyeball, changing the eyeball's axial length and therefore influencing vision. LifeART image copyright 2005 Lippincott Williams & Wilkins. All rights reserved. Annotations added by the author.

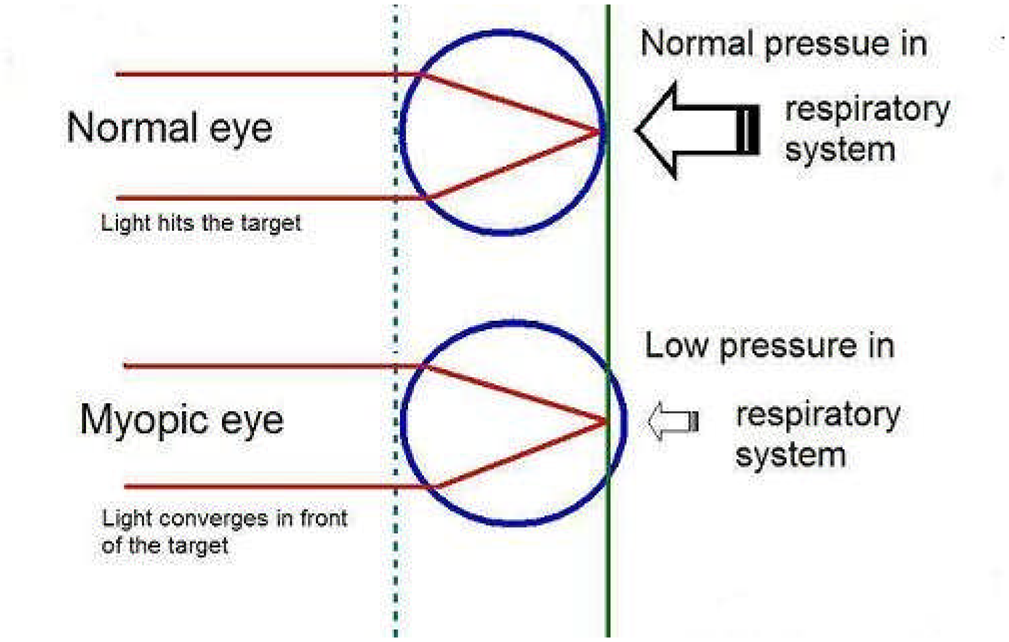

Figure 2. In a myopic eye, light converges at a point in front of the retina. According to Scanlan's General Theory of Myopia, this is due to reduced air pressure from the respiratory system pressing against the back of the eyeball. Paul Scanlan image copyright 2006. All rights reserved.

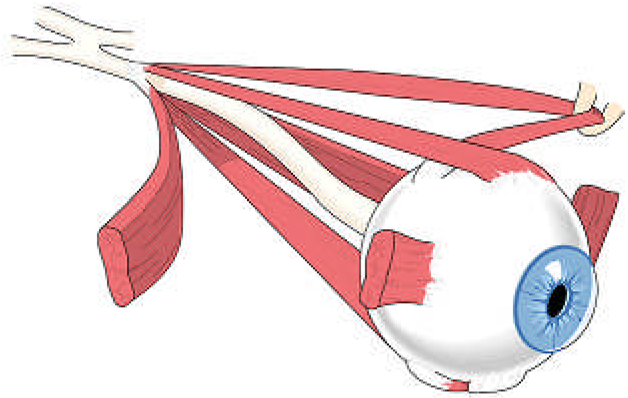

Figure 3. The extraocular muscles and the optic nerve. According to Scanlan's General Theory of Myopia, air pressure from the respiratory system presses against the back of the eyeball and hence influences the shape of the eyeball. LifeART image

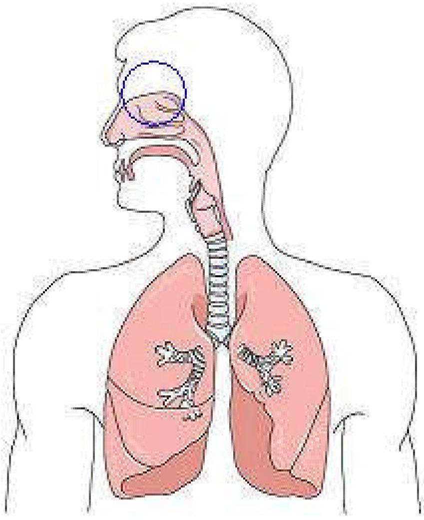

Figure 4. The subject of this paper is the direct influence of the respiratory system on the visual system and the key area of interaction is circled above. According to Scanlan's General Theory of Myopia, the respiratory system transfers pressure to the rear of the eyeball. Adapted by the author from LifeART image copyright 2005 Lippincott Williams & Wilkins. All rights reserved.

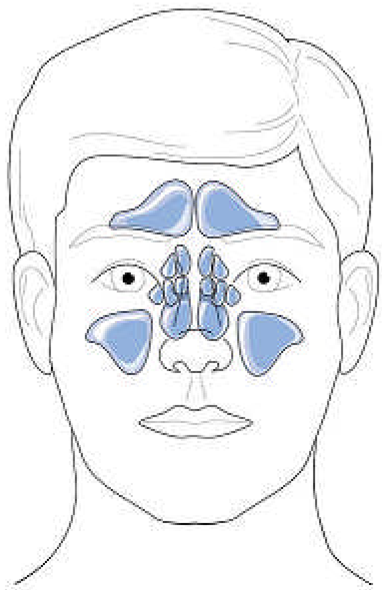

Figure 5. The paranasal sinuses. According to Scanlan's General Theory of Myopia, these sinuses regulate air pressure from the respiratory system that presses against the back of the eyeball. LifeART image copyright 2005 Lippincott Williams & Wilkins.

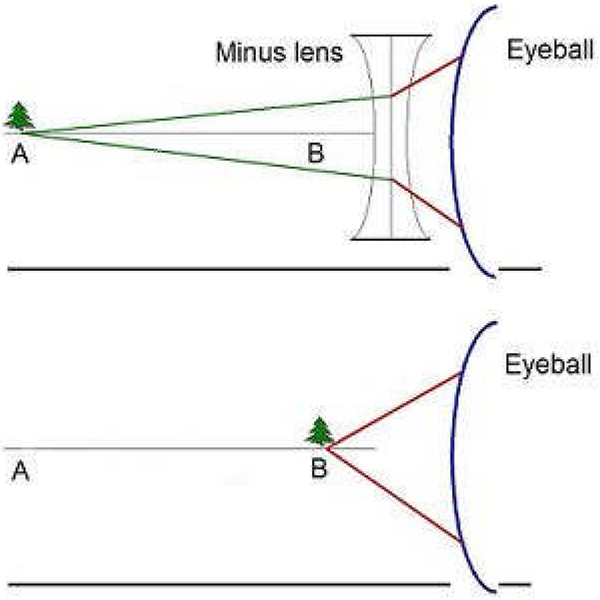

Figure 6. Viewing an object in the distance wearing a minus lens is the equivalent of viewing a much closer object. From the eye's perspective, the optical effect of the minus lens is to bring the tree closer, from point A to point B. Hence the minus lens may effectively increase a person's exposure to near work. Paul Scanlan image copyright 2006. All rights reserved.

[1] For example, see http://www.visioncrc.org/our_activities/myopia.asp.
[2] Fredrick, D. R. Myopia *BMJ* 2002;324:1195-1199 (18 May), accessible at http://bmj.bmjjournals.com/cgi/content/full/324/7347/1195.
[3] Norwak, R. Lifestyle causes myopia, not genes. New Scientist, 8 July 2004, accessible at http://www.newscientist.com/article.ns?id=dn6117
[4] Norwak, R. Ibid.
[5] Schmid, K. Myopia Manual, edition March 2004, accessible at http://www.myopia-manual.de/.
[6] Guyton, D. L. The Physician's Perspective, Health News September 19, 1995, accessible at http://www.chinamyopia.org/healthnewsguyton.htm.
[7] Schmid, K. id.
[8] Schmid, K. id.
[9] Schmid, K. id.
[10] Schmid, K. id.
[11] Schmid, K. id.
[12] Paper by McCollim, Artificially-induced High Myopia and the Mechanism of Accommodation, at http://ec.eurecom.fr/~basturk/eye/papers/mccollim1.txt, citing the review by Hirsch, M. (1967) In Refractive Anomalies of the Eye. Public Health Service Publication No. 1687, National Institute of Neurological Diseases and Blindness, Monograph No. 5, U. S. Department of Health, Education and Welfare 1967. Hirsh, M. A second paper by McCollim also citing this review by Hirsh, M is at http://aarcolin4.net/13598.html.
[13] Bates, W. H. Better Eyesight Without Glasses. At page 20-21.
[14] Schmid, K. id citing Chen C-C, Lin L L-K, Shih Y-F, Hsiao C-H K, Hung PT, Epidemiological studies on multiple risk factors for myopia in Taiwan: gene-environment interaction, in Proceedings of the 7th International Conference on Myopia, Springer, Tokyo 2000, p. 19 and Qiang M, Zhao R, A

logistic regression analysis of relations between juvenile myopia and TV-watching, trace elements, and psychological characteristics, Chung Hua Yu Fang I Hsueh Tsa Chih 1991, Jul; 25(4): 222-224.

[15] News story, NC Enacts Mandatory Eye Exam Law, reproduced at http://www.checkyearly.com/NCEyeExam.html.

[16] Burian, H. and Allen, L. Mechanical changes during accommodation observed by gonioscopy. Arch. Ophthalmol. 54: 66-72, 1955 quoted in a paper by McCollim, R. Artificially-induced High Myopia and the Mechanism of Accommodation, at http://ec.eurecom.fr/~basturk/eye/papers/mccollim1.txt

[17] McCollim, R. Artificially-induced High Myopia and the Mechanism of Accommodation (http://ec.eurecom.fr/~basturk/eye/papers/mccollim1.txt), at Appendix A in reference to the work of investigators including Steiger, cited as Steiger, A. Die Entstehung del Spharischen Refraktionen des menschlichen Auges. Berlin: S. karger, 1913.

[18] Schmid, K. id.

[19] Schmid, K. id citing McBrien N, Structural and metabolic changes associated with recovery from experimentally induced myopia: A brief review, in Proceedings of the 6th International Conference on Myopia, Springer, Tokyo 1998, p. 278, citing Gentle A, McBrien NA, Modulation of scxleral DNA synthesis in development of and recovery from induced axial myopia in the tree shrew, Exp Eye Res 1999 Feb; 68(2): 155-63 and citing McBrien NA, Gentle A, Cottriall C. Optical correction of induced exial myopia in the tree shrew: implications for emmetropization. Optom Vis Sci 1999 Jun;76(6):419-27.

[20] Presentation by Tian. Y and Wildsoet, C. F. Diurnal Fluctuations of Ocular Dimensions and Abberations: Implications for Eye Growth Regulation, School of Optometry, University of California at Berkeley, relevant to NEI Grant NEI R01 EY12392-06 and published online at: http://vision.berkeley.edu/wildsoet/Arvo2005Posters/ARVO2005_Fluctuations%20of%20Aberrations%20and%20Ocular%20Dimensions.ppt and citing studies by Nickla et al 1998, Nickla et al 2002 and Stone et al 2004.

[21] Presentation by Tian. Y and Wildsoet, C. F. id and citing studies by Hofer, H., Artal, P., Aragon, J. L., & Williams, D. R. (2001) Dynamics of the eye's wave aberration. *Journal of the Optical Society of America A*, *18*, 497-506, abstract accessible online at www.pubmed.gov and Cheng, H., Barnett, J. K., Vilupuru, A. S., Marsack, J. D., Kasthurirangan, S., Applegate, R. A., and Roorda, A. (2004) A population study on changes in wave aberration with accommodation. *Journal of Vision*, *4*(4), 272-280, published online at http://www.journalofvision.org/4/4/3/

[22] See Roy, M. Eyerobics. Thorsons, London, 1999; Kaplan, R. The Power Behind Your Eyes. Healing Arts Press, Rochester, 1995; Grunwald, P. Eyebody. Eyebody Press in association with Steele Roberts, 2004; Anghart, L. Vision: the mind side, course notes, NLP Asia Limited, 1998.

[23] Schmid, K. id.

[24] For example, http://100wordminimum.org/archives/000125.html.

[25] Holmes, H. The Skinny On … Strange Sneezing Situations, published online at http://www.discovery.com/area/skinnyon/skinnyon970411/skinny1.html.

[26] Research summarised by Tom Wilson, M.D./PhD, Pathology, Div. of Molecular Oncology, Washington University School of Medicine in Re: Why do we sneeze when we look at the sun? at http://www.madsci.org/posts/archives/aug97/865380242.Me.r.html. Research also summarised in Why do some people sneeze when going out into bright light? Adams, C., 6 September 1985 published in The Straight Dope at http://www.straightdope.com/classics/a2_303.html.

[27] For example, see https://www.suite101.com/article.cfm/our_beautiful_bodies/94095.

[28] Tsubotta, K, Nakamori, K. Dry eyes and video display terminals, N Engl J Med 1993; 328:584.

[29] Sheedy, JE, Gowrisankaran, S and Hayes, JR. Blink rate decreases with eyelid squint, Optometry and Vision Science, Vol 82, No. 10, October 2005 citing Stern, JA, Walrath, LC, Goldstein, R. The endogenous blink. Psychophysiology 1984; 21:22-33 and citing Karson, CN. Physiology of normal and abnormal blinking. Adv Neurol 1988; 49:25-37.

[30] BBC article, Blink and you really do 'miss it', published online at http://news.bbc.co.uk/1/hi/health/4714067.stm.

[31] For example, blink rate studies are summarised in In the blink of an eye - research on blinking as by-product of mental processes, Psychology Today, March 1988 by Susan Chollar, which can be accessed using www.findarticles.com; and Estimates of impressions based on frequency of blinking, Social Behaviour and Personality, 2001, Omori, Y. and Miyata, Y. which can be accessed using www.findarticles.com.

[32] Rosin, D. Headache, published at WebMD at http://www.webmd.com/content/article/4/1680_51343.

[33] Lewandowski, K. et als. Low nitric oxide concentrations in exhaled gas and nasal airways of mammals without paranasal sinuses. J Appl Physiol 85: 405-410, 1998. This article is available at http://jap.physiology.org/cgi/content/full/85/2/405.
[34] Ehealth MD, Endoscopic Sinus Surgery, What Are The Most Common Complications? published at http://www.ehealthmd.com/library/endosinus/ESS_complications.html.
[35] Emedicine, Functional Endoscopic Sinus Surgery, Patel, A. M. 31 October 2005 published at http://www.emedicine.com/ent/topic758.htm.
[36] Chopra, H. et als, Invasive fungal sinusitis of isolated sphenoid sinus in immunocompetent subjects, Mycoses 2006 Jan;49(1):30-6; abstract accessible using http://www.ncbi.nlm.nih.gov/entrez/query.fcgi.
[37] Cunha, LP et als, Severe bilateral visual loss as the presenting sign of cerebral venous sinus thrombosis: case report, Arq Bras Oftalmol 2005 Jul-Aug;68(4):533-7. Epub 2005 Nov 22; accessible using http://www.ncbi.nlm.nih.gov/entrez/query.fcgi.
[38] Rosin, D. Headache, published at WebMD at http://www.webmd.com/content/article/4/1680_51343.
[39] For example, anecdotal observations of this nature is found at http://blog.kvpug.org/2005/08/got-my-new-glasses.htm, at http://weblogs.mozillazine.org/josh/archives/2005/09/glasses.html and at http://www.dvdtalk.com/forum/printthread.php?t=410215.
[40] See for example http://neuro.med.harvard.edu/site/dh/b14.htm#topo.
[41] Cook, D. Visual Fitness, 7 Minutes to Better Eyesight and Beyond, Berkley Books, New York, 2004.
[42] Cook, D. Ibid.
[43] Schmid, K. id citing Drexler W, Findl O, Schmetterer L, Hitzenberger CK, Fercher AF, Eye elongation during accommodation in humans: differences between emmetropes and myopes, Invest Ophthalmol Vis Sci 1998 Oct; 39(11): 2140-7.
[44] Schmid, K. id quoting Drexler et als ibid.
[45] For example, see http://www.aafamilykarate.com/belt_testing_questions_and_answe.htm.
[46] Presentation by Tian. Y and Wildsoet, C. F. id citing studies by Hofer, H., Artal, P., Aragon, J. L., & Williams, D. R. (2001) Dynamics of the eye's wave aberration. *Journal of the Optical Society of America A*, *18*, 497-506, abstract accessible online at www.pubmed.gov and Cheng, H., Barnett, J. K., Vilupuru, A. S., Marsack, J. D., Kasthurirangan, S., Applegate, R. A., and Roorda, A. (2004) A population study on changes in wave aberration with accommodation. *Journal of Vision*, *4*(4), 272-280, published online at http://www.journalofvision.org/4/4/3/
[47] Hofer, H., Artal, P., Aragon, J. L., & Williams, D. R. (2001) Dynamics of the eye's wave aberration. *Journal of the Optical Society of America A*, *18*, 497-506, abstract accessible online at www.pubmed.gov.
[48] Stark, J. and Stark, R. The Carbon Dioxide Syndrome. Buteyko On Line Ltd, Auckland 2002, citing Naifeh, K. Behavioural and Psychological Approaches to Breathing Disorders. Ed. B.H. Timmons & R Ley. Plenum. New York. 1994.
[49] Stark, J. and Stark, R. id citing Cottle, MH. The work, ways, positions and patterns of nasal breathing (relevance in heart and lung illness). Proceedings of the American Rhinologic Society. 1972.
[50] Stark, J. and Stark, R. id citing Tortora, GJ, Anagnostakos, NP. Principles of Anatomy and Physiology, Harper & Row, New York. 1984, and citing Kapit W, Macey RI, Meisami, E. The Physiology Colouring Book. Addison Wesley Longman Inc. San Francisco. 2001.
[51] Stark, J. and Stark, R. id citing Lumb, AB. Nunn's Applied Respiratory Physiology. Reed. London. 2000.
[52] Peper, E. and Tibbetts, V. Effortless Diaphragmatic Breathing, in Electromyography, published online at http://www.bfe.org/protocol/pro10eng.htm.
[53] Stark, J. and Stark, R. id.
[54] Schmid, K. id.
[55] Stark, J. and Stark, R. id, and Peper, E. and Tibbetts, V. id.
[56] Stress Management from Mind Tools, What Stress Is … Definitions, published at http://www.mindtools.com/stress/UnderstandStress/StressDefinition.htm.
[57] For example, Roy, M. id.
[58] Schmid, K. id citing Goldschmidt, E. Epidemiology of Myopia: Scandinavian and Hong Kong experiences in Myopia Updates, Proceedings of the 6th International Conference on Myopia, Springer, Tokyo, 1998.
[59] Schmid, K..
[60] Liberman, J. Take Off Your Glasses and See. Crown Pub. 1996.
[61] Schmid, K. id citing Schultz-Zehden W, Bischof F, Auge und Psychosomatik, Deutscher Aerzte Verlag, Köln, 1986.

[62] Stark, J. and Stark, R. id citing Bowler, SD et al. Buteyko breathing techniques in asthma: a blinded randomised controlled trial. MJA 1998. 169. pp575-578, and citing Hibbert, GA, Pilsbury, DJ, Demonstration and treatment of hyperventilation causing asthma. British J Psych. 1988. 53. pp687-689.
[63] Stark, J. and Stark, R. id.
[64] Storfer, M.D. (2000) Myopia, Intelligence, and the Expanding Human Neocortex, Psycoloquy: 11,#83 Brain Intelligence (1), which is published at http://psycprints.ecs.soton.ac.uk/archive/00000083/.
[65] Schmid, K. id citing Dolezalova V, Mottlava D, Relation between myopia and intelligence, Cesk Oftalmol 1995 Sep; 51(4): 235-9.
[66] Schmid, K. id citing Pizzarello LD. Refractive changes in pregnancy. Graefes Arch Clin Exp Ophthalmol 2003 May 8.
[67] For example, WebMD, Hyperventilation topic overview, published at http://www.webmd.com/hw/health_guide_atoz/tp2736.asp.
[68] Roy, M. id, Kaplan, R. id, Grunwald, P. id; Anghart, L. d
[69] Capital Hyperbarics Limited at http://www.capitalhyperbarics.com/WhatisHBODr.htm.
[70] Palmquist, BM Philipson, B and Barr, PO. Nuclear cataract and myopia during hyperbaric oxygen therapy, British Journal of Ophthalmology, 1984, Vol 68, 113-117; the abstract is accessible at http://bjo.bmjjournals.com/cgi/content/abstract/68/2/113.
[71] See for example http://pedia.nodeworks.com/H/HY/HYP/Hyperbaric_oxygen_therapy.
[72] See for example http://www.hot4rcpkidsfoundation.on.ca/questions_and_answers.htm and http://www.florida-oxygen.com/treatment.htm.
[73] See for example http://www.stlukeseye.com/anatomy/ExtraocularMuscles.asp.
[74] Fischer, MD, Budak, MT, Bakay, M, Gorospe, JR, Kjellgren, D, Pedrosa-Domellof, F, Hoffman, EP, Khurana, TS. Definition of the unique human extraocular muscle allotype by expression profiling. *Physiol. Genomics* 22: 283-291, 2005, accessible at http://physiolgenomics.physiology.org/cgi/content/full/22/3/283
[75] Cook, D. id and http://www.children-special-needs.org/strabismus/strabismus.html.
[76] See for example http://www.visionandlearning.org/glossary.htm.
[77] See for example Santhanaraj, V. Reading performance in foveal and peripheral vision, accessible at http://www.icevi.org/publications/ICEVI-WC2002/papers/03-topic/03-santhanaraj.htm.
[78] Fischer, MD et als id.
[79] For example, see Jacob, A; Faddis, BT, Chole, RA, Chronic Bacterial Rhinosinusitis: Description of a Mouse Model, Arch Otolaryngol Head Neck Surg 2001; 127: 657-664 accessible at http://jama.ama-assn.org/cgi/collection/general_rhinology?notjournal=jama,amajnls&page=12 and http://www2.kumc.edu/otolaryngology/resid.htm.
[80] See in particular Brown, O. S. How to avoid nearsightedness, C & O Research, Bowie, 1989.
[81] See http://www.buteyko.info/ and http://www.resperate.com/.