

## Incidence of Meares-Irlen/visual stress syndrome in reading and learning disorders: does fluorescent lighting in classrooms affect literacy and numeracy?

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In recent years there has been mounting discussion in educational psychology journals concerning the incidence of school students in developed nations with inadequate literacy and numeracy skills. There has also been evolving debate as to whether these vital skills have only been declining in Western countries. Adding to the current discourse surrounding educational issues, the media has seemingly had little difficulty obtaining anecdotal reports from employers and tertiary educators suggesting that a decline in literacy and numeracy skills first became noticeable in school leavers during the 1990s. This theoretical critique examines the literature pertaining to both recent and long term trends in literacy and numeracy in OECD countries. The degree to which changes to the classroom environment in recent decades may have adversely impacted upon certain reading and learning disorders is also scrutinised. In particular, this report evaluates the role that a specific visual perception deficit (Meares-Irlen/visual stress syndrome) may play in overall literacy and numeracy statistics, and explores the added possibility that the trend towards increased fluorescent lighting and bright visual media in classrooms have enhanced that contribution. Thus, the scientific literature presented in the following pages encompasses diverse areas of research.

*Keywords:* Visual perception, reading, mathematics, visual stress syndrome.

*Incidencia del síndrome Meares-Irlen / estrés visual en los trastornos de la lectura y el aprendizaje: ¿afecta la iluminación fluorescente en el aula a la adquisición de la lectoescritura y la aritmética?* En los últimos años ha aumentado el número artículos recogidos en revistas de Psicología de la Educación que discuten acerca de la incidencia de alumnos con bajo nivel de alfabetización y bajas habilidades aritméticas en las aulas. Por otro lado, en relación al ámbito de la educación, los medios no han tenido dificultades para obtener, de manera informal, datos de empleados y educadores que sugieren un descenso en las competencias académicas, de alfabetización y numéricas. Este trabajo examina la literatura perteneciente a los años 90 y la actualidad, donde se observan problemas relacionados con la alfabetización y las habilidades aritméticas en los países de la OCDE. También se analiza en qué medida los cambios en el contexto del aula pueden haber tenido un impacto negativo en la lectura y dificultades del aprendizaje. En concreto, se analiza el papel que puede estar jugando un déficit específico de percepción visual (síndrome Meares-Irlen / estrés visual) en los procesos de alfabetización y adquisición de habilidades aritméticas, explorando la posibilidad de que la actual tendencia a integrar iluminación fluorescente y medios visuales brillantes en las aulas, hayan contribuido a aumentar las dificultades en la adquisición de estas habilidades.

*Palabras clave:* Percepción visual, lectura, matemáticas, estrés visual.

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In the past two decades there has been increasing awareness of a common visual processing deficit known as Meares-Irlen syndrome and more recently referred to as Visual Stress (VS). Individuals with this condition

report various distortions of print when reading, such as text appearing to move or vibrate, despite being found to have no optometric or ophthalmological abnormalities. Their span of word recognition (the number of words seen in one eye-fixation) is also greatly reduced, as is their ability maintain extended reading (Robinson, 1994). These symptoms inherently affect reading, writing, spelling and visual attention, and thereby often compromise the learning potential of affected individuals. This can be the case regardless of the academic levels a student may achieve, as the condition is equally prevalent across all levels of intellectual ability and knows no socio-economic boundaries. As a result, symptoms of VS in children can easily be misinterpreted as signs of laziness or inattention. However, many affected individuals learn to compensate for the above difficulties as VS is not a learning disorder in the strict sense, but rather, a visual-perception dysfunction which can significantly hinder reading-based learning.

Estimations of the VS prevalence in the general population vary between 5% using strict criteria, such as an immediate improvement ( $\geq 25\%$ ) in reading speed when reading through coloured transparencies placed over text (Kriss, & Evans, 2005) and 20 to 25% when the reported symptoms of visual discomfort and print distortions form the basis of diagnosis (Robinson, Hopkins, & Davies, 1995; Allen, & Hollis, 2008). However, there appears to be a general consensus that incidence estimates of moderate to severe VS in the vicinity of 12% are reasonable (Kriss, & Evans, 2005; Jeanes et al., 1997; Evans, 2004). Although VS is often referred to as a sub-type of dyslexia (Sparkes et al., 2006), this categorisation remains highly contentious. Others describe VS as a separate entity which can occur with or without dyslexia, albeit notably more prevalent (31% to 46%) in the dyslexic population (Kruk, Sumblor, & Willows, 2008). Identification of VS morbidity may be further complicated by the fact that similar symptoms have been identified in other disorders (Robinson et al., 2001). One such disorder is attention deficit/hyperactivity disorder (ADHD), the reported incidence of which

has increased dramatically during the past two decades. Symptoms of ADHD are known to overlap with symptoms of VS and/or dyslexia (Taurines et al., 2010), with inattention and off-task behaviour tending to increase when children with either VS or ADHD are under bright fluorescent lighting (Ott, 1976; Irlen, 1994).

Several studies have investigated the possible effects of fluorescent lighting upon visual comfort and visual acuity (Boyce, 1994; Navvab, 2001; Winterbottom, & Wilkins, 2009) with the latter study proposing that visual discomfort and migraine headaches in certain individuals are caused by the 100 Hz flicker of this form of lighting. Curiously, the majority of such lighting research has focused almost exclusively upon comparisons of different fluorescent lamp-types (Kuller, & Laike, 1998; Veitch, & McColl, 1995, 2001), while studies comparing visual discomfort under fluorescent lighting against other forms of illumination (eg. incandescent lighting) remain conspicuously absent from the literature.

### *Hypothesis*

On the basis of converging evidence, it is herein hypothesised that declining or, at best, stagnate literacy rates in OECD countries over the past three decades may in large part be due to significantly increased fluorescent lighting in schools over the same period. Although such a hypothesis might at first glance appear to be over-simplistic, the dynamics upon which this hypothesis is based include the following factors: 1) visual acuity is known to be influenced by chromaticity; 2) brightness perception is largely determined by the spectrum of a given form of lighting; 3) spectral emissions from fluorescent lighting are vastly dissimilar to other forms of illumination; 4) installation of fluorescent lighting into primary schools coincides well with the rise to prominence of unexplained reading and learning disorders; 5) reported declines in student levels of literacy and numeracy since the 1970s are a negative correlate of significant increases in the number and brightness of fluorescent lamps in schools; 6) break-throughs in bleaching technologies during the 1980s allowed paper

manufacturers to emulate trends in the lighting industry by significantly increasing the brightness ('ultra-whiteness') of reading and writing material; 7) peer-reviewed research indicates that at least 12% of students have moderate to severe symptoms of VS and are thus affected by the former factors.

### *Evidence*

#### *Classroom Lighting: what has changed in recent decades?*

1) *Brightness and Glare Levels:* Studies examining artificial illumination are by no means a new area of research, however it is only in the last 20 years that researchers, such as Berman et al. (1990, 1993), began to question the appropriateness of typically high levels of interior illumination in workplaces and schools. The possible relationship of brightness and glare to reading and learning difficulties became an area of research interest even more recently (Veitch, 2001; Wilkins, Huang, & Cao, 2007; Winterbottom & Wilkins, 2009), with some studies reporting that excessive lighting (particularly fluorescent lighting) can provoke headaches and visual stress in susceptible populations. The study by Winterbottom and Wilkins (2009) measured lighting flicker-frequencies, desk-illuminance and reflected glare in a sample of 90 classrooms (across 17 schools) and found that the lighting in 88% of British classrooms exceeds illuminance recommendations, with 84% having highly excessive illumination. The study reported that the amount and type of lighting in schools can affect reading, and that any negative effects upon learning due to excessive lighting were likely to be further compounded by the reflected glare from whiteboards and other bright visual media.

Why, then, might building designers have a propensity to over-illuminate office and classroom settings in the first place? According to Berman et al. (1996), this is in large part due to significant shortcomings in general lighting practice guidelines. The above researchers reviewed a wealth of ophthalmological and vision science research, and then compared this literature to contemporary publica-

tions emanating from lighting industry associations, such as the Illuminating Engineering Society of North America (IESNA). They found the primary problem to be that virtually all lighting guidelines, and for that matter the calibrations of all illuminance-measuring devices, are based upon the light sensitivity of only one of the two key types of photoreceptors in the retina.

The fact that our eyes have two types of photoreceptors (the *rods* and the *cones*) has been known since early last century, although a third photoreceptor believed to be linked to circadian rhythm has recently been discovered (He et al., 2003). Conversely, the roles of the rod and cone retinal cells have long been established, with the rods recognized as being night vision (scotopic) receptors and the cones as being day vision (photopic) receptors. However, according to Berman et al. (1996) this traditional view is not only over-simplistic, but is also based upon outdated optical measurements which appear to have been designed "more for observational convenience, rather than scientific accuracy".

The basis upon which rod receptors were first assigned with the single role of being night vision receptors has been hitherto determined through measurements of rod cell responses (scotopic sensitivity) under clearly inadequate conditions (Berman et al., 1996). These measurements (to which all lighting industry guidelines still adhere) have traditionally been carried out under extremely low light levels designed to be well below the threshold of cone sensitivity, thereby excluding any visual input from cone receptors. It appears that because rod receptors can be shown to function efficiently in very faint light, which is well below the sensitivity threshold of cone receptors, this finding has then been extrapolated to indicate that the rods are solely night vision receptors. However, the fact that very dim lighting conditions are utilised to isolate rod receptor responses does not automatically rule out the functioning of rod sensitivity at higher light levels, particularly those of typical interior lighting.

In a similar fashion, the methodology employed to measure visual input from cone re-

ceptors (photopic sensitivity) has traditionally been carried out under highly unrealistic conditions, which are even more restrictive than those utilised to ascertain rod receptor responses. Indeed, photopic sensitivity is still routinely measured by constricting the test subject's field of view to a maximum of 2 degrees (less than 0.1% of the normal field of view of the human eye) in order to exploit the absence of rod photoreceptors in the central portion of the retina, thus isolating and measuring only the cone responses (Bouma, 1962; Berman et al., 1990, 1996). As a result of these longstanding methods, virtually all current lighting industry recommendations for measuring indoor illuminance and estimating optimal room brightness have been based solely upon the sensitivity of only one of the two key photoreceptor cell types: the cone receptors (responsible only for photopic sensitivity). The now widely recognised contribution of the rod receptors (scotopic sensitivity) to vision at typical interior lighting levels has been completely excluded from such guidelines, despite the significance of the scotopic contribution under artificial lighting being reported upon some 16 years ago in the prestigious *Journal of the Illuminating Engineering Society*, (Berman et al., 1997). Hence, lighting industry guidelines pertaining to optimal interior illumination have remained unaltered, and evidence of this can be readily found in recent editions of lighting guidelines (eg: *IESNA Illumination Handbook*).

2) *Spectrum and Colour Ratios*: Some researchers propose that because the Sun has been the primary lighting source throughout human evolution, it only stands to reason that the human visual system has probably evolved to function most efficiently in light emitting similar spectral properties to sunlight (Thorington et al., 1971; Wurtman, 1975a, 1975b; Hughes, 1980). In considering this view, it is worth noting that until the advent of fluorescent lighting, virtually all visible light entering human eyes had emanated from thermal sources, such as the Sun, fire, candles, oil or gas lamps and eventually incandescent bulbs, all of which produce a continuous spectrum with the majority of light emitted in the yellow, orange and red bands.

The spectral power distribution (SPD) of fluorescent lamps (Figures 1b; 1c) however, is vastly different to the SPD emitted by thermal sources of light, such as incandescent light-bulbs (Figure 1a). In particular, the ratio of short wavelength light (violet to blue) to longer wavelength light (yellow to red) is several fold greater in the spectrum emitted by fluorescent lamps. Another significant dissimilarity between these two forms of illumination is that a graph of the spectrum produced by incandescent lighting forms a continuous curve, which is also the case for sunlight, whereas the spectrum emitted by fluorescent lighting does not remotely resemble a continuous curve. The SPD graphs shown below (Figure 1) also suggest that the relatively recent development of tri-phosphor fluorescent lamps constitutes a further shift away from the use of lighting sources with a continuous spectrum.

The fact that differing spectral distributions can affect visual performance and brightness perception has been shown in several studies (Berman et al., 1993, 1996; Navvab, 2001, 2002). These studies demonstrated that visual acuity is largely determined by pupil size which, in turn, is a determinant of the proportion of the illumination emitted in the shorter wavelength bands. Such research not only revealed that the blue and green regions of the visible spectrum evoke a disproportionately high visual system response to light, by way of the rod photoreceptors (the scotopic response), but also demonstrated that the human perception of illumination brightness is a positive correlation of this response. The data relating to pupil size in these studies can only be viewed as entirely objective, simply because trial participants cannot voluntarily alter the size of their pupils.

An earlier study by Berman et al. (1990) demonstrated just how easily the perception of brightness can be affected by changes in the spectral distribution of interior lighting. A group of lighting technicians were asked to assess which of two room lighting conditions appeared brighter. The chromaticity specifications of the two types of lighting provided equal colour appearance of the room and its contents. One form of lighting emitted a spectral distribution favouring rod excitation (thus, enhanc-

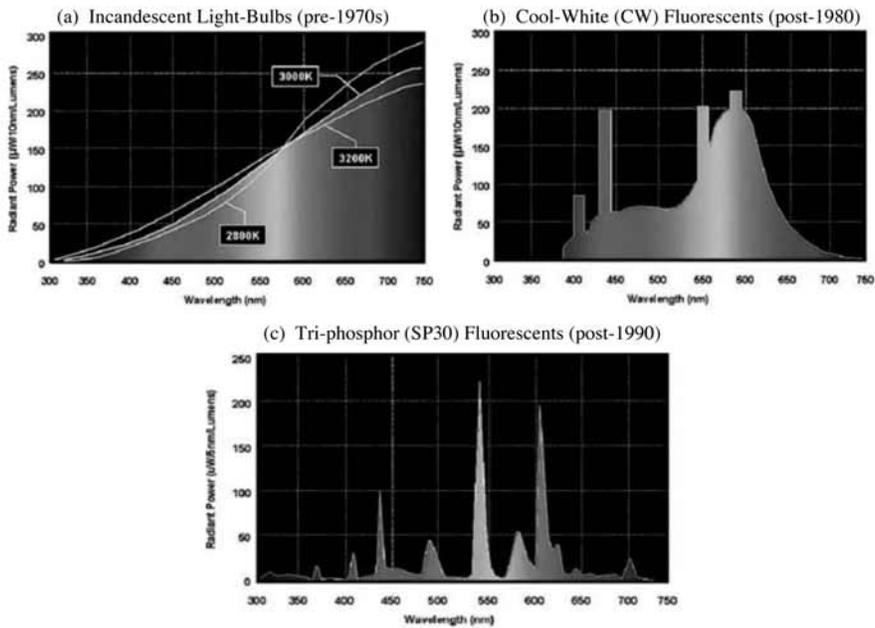


Figure 1. *Changes to Classroom Lighting in Australian Primary Schools since mid-1970s. (a) SPD of incandescent lights; (b) SPD of cool-white fluorescents; (c) SPD of tri-phosphor fluorescent. (Source: www.gelighting.com/na/business).*

ing the scotopic response), however, conventional illumination measurements showed this to be 30% dimmer than that produced by the second form of lighting. Interestingly, the participants repeatedly chose the weaker illumination as appearing brighter. These findings agree with research by Navvab (2001, 2002) showing that the proportion of shorter wavelength light (the ‘scotopic content’) emitted by indoor lighting is the dominating factor affecting visual comfort and performance, not the overall degree of room illumination. Ray, Fowler and Stein (2005) further demonstrated that optimal artificial lighting for reading requires an adequate proportion of longer wavelength light in its spectral emissions, by showing that yellow filters enhance convergence, accommodation, and reading.

*Literacy and Numeracy Levels: have they also changed in recent decades?*

The above question has spurred a plethora of educational studies, however very few investigations have sought to resolve this ques-

tion by reviewing literacy and numeracy test-score data over several decades. In countries such as Australia, it seems that politicians and education authorities have traditionally preferred to base their assessments of national literacy and numeracy achievement levels almost exclusively upon international comparisons, and are thus quick to point out that recent student test-scores have not slipped in the OECD rankings of international literacy and numeracy performance. However, a perception of stable literacy and numeracy achievement based only upon comparisons with OECD nations might well be illusionary if, for instance, it were to be the case that many such countries had themselves experienced declines in these key measures. In addition, the ease of literacy acquisition in any given country greatly depends upon the specific language in which a student must become literate (Dehaene, 2009). Indeed, the data presented below (Figure 2) suggests that in phonetically “transparent” languages, such as Spanish and German, attaining proficient levels of literacy is far less of



Figure 2. Variations in Early-childhood Literacy Achievement in Europe  
(Excerpted from: Dehaene, 2009, 'Reading in the Brain')

a learning task than in relatively “opaque” languages such as English.

Thus, any assessment of a nation’s progress in literacy and numeracy should also peer inwards, and gauge its contemporary appraisal of these skills against that country’s own long term records of school-based testing in these areas. In this respect, it seems that there have been very few comprehensive studies of medium to long term trends in literacy and numeracy test-scores. However, a recent study (Leigh, & Ryan, 2010) carried out at the Australian National University, Canberra, tracked the performance of 13-14 year-old Australian students in national literacy tests from 1975 to 1998, and in numeracy tests from 1964 to 2003.

The study by Leigh and Ryan (2010) had selected the above time-frames purely on the basis that only during these two periods were successive groups of Australian school students presented with identical questions. The researchers found a significant decline in numeracy between 1964 and 2003, with Year 9 students in 2003 being approximately a quarter of a grade behind their 1964 counterparts. Moreover, this decline had occurred in spite of an increase in per-child educational funding of 258% (in real terms) and a 43% fall in class sizes during the same period. There were

also significant declines in both literacy and numeracy in the testing results of both male and female students between 1975 and 1998.

The above trends in literacy and numeracy are not peculiar to Australia and have indeed been observed in other developed nations. In the United States, literacy and numeracy test-scores have reportedly remained flat from 1970 to 1998, even though per child education expenditure rose by 2.5–3% per year (in real terms) over the same period (Hanushek, 1997; Hoxby, 2001). From a wider international perspective, a review of literacy and numeracy test results in 11 developed nations in a study by Gundlach, Woessmann and Gmelin (2001) found that progress in these key areas of education had essentially remained flat in OECD nations from 1970 to 1994. The study further noted that this had occurred in spite of dramatic increases in per-child spending in most developed countries over the same period.

Increased investment in education by the British government appears to have shown equally poor returns, with a study by Flynn (2009) revealing that the literacy and numeracy test-scores of 14-15 year-old students between 1980 and 2008 had declined. However, the creditable test-scores achieved in many poorer nations seem to suggest that higher scores are not

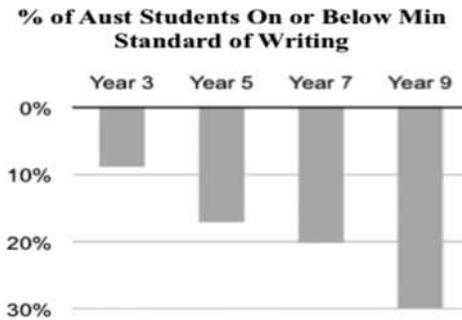


Figure 3. *Trend of Progression in Writing Literacy through High School (Excerpted from: 'Measuring what matters: Student progress', School Education, 27 Jan, 2010)*

necessarily a direct correlate of higher education spending. In respect to the reliance on OECD education comparisons as a guide to a nation's literacy levels, recent data relating to Australia (Figure 3) clearly demonstrates that it is possible for a nation to have a literacy dilemma while still being ranked sixth in OECD international reading tests (PISA 2009).

Reports of declining trends in literacy and numeracy across such a wide range of nations might perhaps suggest that, at some point during the past few decades, changes to certain aspects of the teaching methodologies and/or classroom environments common to developed countries may have negatively affected literacy and numeracy acquisition. If so, the above studies would appear to implicate the 1970s to early 1980s as the time-frame in which any such changes are likely to have first been implemented. Perhaps coincidentally, fluorescent lighting was not installed into the classrooms of Australian primary schools until the mid-1970s. Thus, the first children to have commenced kindergarten under this form of lighting were entering the workforce and university circa 1990, or around the same time as declining literacy first became a topical issue amongst tertiary educators in Australia.

#### *Visual Stress Prevalence: why the lack of community awareness?*

A comprehensive study commissioned by the UK parliament recently reported that dyslexia is prevalent in 4-8% of English-speaking populations (Rose, 2009), and the British

Dyslexia Association has produced similar figures. Indeed, the website of NEURODYS, the largest multi-national study of dyslexia ever undertaken, currently reports that dyslexia affects the educational outcomes of at least 5% of European school children. In respect to the prevalence of VS, several studies have consistently reported incidences in the realm of 5-15% (Jeanes et al., 1997; Kriss & Evans, 2005) with some estimates being as high as 20-24% (Robinson, Hopkins, & Davies, 1995). However, pin-pointing the precise incidence is made difficult by the severity of VS morbidity being a continuum (Evans & Joseph, 2002).

As the VS condition appears to be far more prevalent than either developmental dyslexia, or ADHD, one might logically question the reasons for its much lower profile amongst educators, physicians, researchers and for that matter, the wider community. One possible explanation is that many VS individuals are not necessarily affected to such a degree that they are clearly unable to read or write efficiently (dyslexia by definition). Rather, it is typically the case that only the lack of *fluency and speed* in a VS individual's reading and writing abilities are obvious, and often these mild limitations only tend to deteriorate after reading continually for more than 5-10 minutes (Tyrrell, 1995). It stands to reason, therefore, that a few minor deficiencies in the oral reading of a passage of text may not necessarily arouse a great deal of attention in a child's educators, or their parents. Moreover, any literacy and numeracy tests of relatively short duration are unlikely to

fully detect a VS individual's weaknesses in these areas. Potentially complicating the recognition of VS symptoms still further, is the fact that many affected individuals often develop coping strategies at an early age, such as the avoidance of prolonged oral reading in front of teachers and peers.

There are two additional factors which further confound the identification of VS morbidity:

1) *Comorbidity between VS and other learning disorders is common*: Several studies have reported on the exceptionally high incidence of comorbidity among VS, dyslexia, and other disorders affecting reading, with some proposing that a significant genetic component is likely to provide the most viable explanation for this phenomenon (Chen et al. 2004; Haag 2003; Loew, & Watson, 2012; Richardson 2004; Robinson et al., 2001).

2) *Misinterpretation of VS symptoms as signs of ADHD*: The degree of symptom overlap between VS and ADHD has recently been shown to be far higher than previously reported (Taurines et al., 2010; Loew, & Watson, 2013). In the latter study, the incidences of nine diagnostic symptoms of VS were surveyed in a group of subjects ( $n = 12$ ) diagnosed with ADHD, and a group of individuals ( $n = 18$ ) diagnosed with VS. There were no statistically significant differences in the incidences of seven of the symptoms between these two groups. The study thus concluded that there is an inherent potential for VS to be misdiagnosed as ADHD and that this may partly account for the unexplained growth in ADHD diagnoses in recent decades, particularly the 30% of those diagnosed who do not respond to treatments.

### Conclusions

There appears to be convincing evidence that Meares-Irlen/visual stress syndrome is prevalent in a significant proportion of the general population, and that affected individuals are particularly disadvantaged when reading in fluorescent lighting. Whether the incidence of visual stress is 5% or 15% is not at issue, as most learning disorders currently un-

der intensive research on an international level are present in no more than 5% of the general population. The literature also contains the findings of several studies indicating that differing forms of interior lighting can affect visual acuity, visual-task performance, concentration and fatigue in most individuals, not only those with VS. A great deal of the peer-reviewed literature further suggests that typical primary school classrooms in developed nations (24 - 30 pupils) are likely to contain three or four students who are being significantly disadvantaged by the use of bright visual media, such as ultra-white paper and highly reflective whiteboards, in combination with excessive fluorescent lighting.

In respect to the studies reporting excessive lighting in classrooms, and anecdotal reports of progressively increasing levels of illumination in schools, offices, and even supermarkets, it has not escaped the author's attention that the lighting industry may well have a vested interest in adhering to the outdated illumination guidelines which have remained in place since 1928. Similarly, the drift away from lighting with a continuous spectrum also seems to be commercially rather than ergonomically driven, as the recent demand for energy-efficient lighting has prompted the lighting industry to develop 'brighter and whiter' fluorescent lights. However, the newer generations of energy-efficient 36-Watt fluorescent tubes, of course, consume exactly the same amount of energy as the older 36-Watt tubes that preceded them, with the added brightness ('efficiency') simply being achieved by shifting the SPD towards the blue-violet (scotopic) end of the visible spectrum. This effectively tricks the brain into 'perceiving' (via the scotopic response of the rod cells) that a room and its contents appear brighter. The same principal has long been used in laundry detergents marketed as clothing-whiteners, when in actual fact a small amount of blue-dye is simply added to the formula.

In summary, underlying causes are continually being sought to explain the persistently high incidences of students with poor literacy outcomes in several developed nations. It is therefore surprising that educational re-

searchers appear to have not tapped into the wealth of related research available in adjacent fields. If one considers the prevalence of visual stress; the above-cited evidence that similar symptoms can be present in other learning disorders; the research showing that fluorescent lighting is known to exacerbate such symptoms; and the data showing that literacy and numeracy levels have declined over the same period as levels of fluorescent lighting in classrooms have progressively increased,

then surely the focus of some educational research might be better directed towards visual and sensory deficits.

The hypothesis presented here appears to fit well with the three aspects of research examined as potential evidence that changes to classroom lighting may be affecting literacy and numeracy, both biophysically and chronologically. Thus, in the absence of conflicting evidence or alternative elucidation, the author concludes that the hypothesis remains viable.

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