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Colored Filters and Dyslexia. A Quick Gliding over Myth and (Possible) Reality

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Abstract Since the early Eighties, a great deal of literature is debating the rehabilitative role of colored filters in developmental dyslexia. It has been advocated that the use of the so-called "intuitive overlays" and of individually chosen colors can be beneficial in disabled readers, improving reading rate and/or comprehension. However, in absence of a sound theory accounting for the individual preferences in color, such approach lacks scientificity and its putative effectiveness is likely to depend on placebo effect. Notwithstanding, it has been shown that the magnocellular pathway, whose abnormal inhibition is believed to be responsible for part of the reading impairment in dislexics, can be sensitive (and as such modulated) by certain light wavelength. In particular long wavelengths (red light) would have a suppressive effect whereas short wavelengths (blue light) would enhance its function. Based on this rationale, research on colored filters and its applicability on reading disabilities might provide a promising rehabilitative approach.

Keywords: *dyslexia, colored filters, magnocellular, wavelengths*

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1. Introduction

Since the early Eighties, a great deal of literature is debating the potential effect of colored filters in improving reading function in subjects suffering from asthenopeic symptoms, as well as in dyslexic readers.

More specifically, It has been stated that colored filters are effective in relieving the so-called visual stress syndrome, generically defined as "the inability to see comfortably and without distortion" [1]. Visual stress is argued to be consequence of exuberant sensorial stimulation of visual cortical areas [2,3] and colored overlays or spectacles would act by decreasing such over-excitation via selective absorption of certain light wavelengths. Based on a few studies relating visual stress syndrome to developmental dyslexia (see for example Singleton & Trotter [4]), colored filters have been suggested to improve reading performance in disabled readers by relieving visual stress [5,6,7,8].

It is singular, however, that the selection of the optimal filter is individually chosen, that is to say it is dictated time after time by the reader, so that the color chosen by one subject can be different from the color preferred by another one.

Irrespective of the evident lack of scientificity, the apparent ameliorative effect of such so-called intuitive colored filters [9] (be they mounted on spectacles or prescribed as overlay) on reading and related visual stress in dyslexic subjects has not been confirmed.

To this end it should be recalled that the proportion of dyslexics putatively suffering from visual stress is just 10% higher than the normal readers, leading to conclude that visual stress syndrome has little to do with dyslexia [10]. Indeed visual stress, when reported in dyslexics, is likely to stem from the effort to read properly rather than being a separate, additional condition. Therefore, it should be bore in mind that on the one hand visual stress is not a main symptom complained by dyslexic patients, on the other hand that visual stress is a *symptom* while dyslexia is a *syndrome*.

This paper aims at briefly considering within a rationale frame the effect colored filters may have on the reading performance of poor readers and in particular on dyslexic children, irrespective on the co-occurrence of visual stress.

The effectiveness of the intuitive colored overlays has been denied in poor readers as well as in dyslexic subjects, despite few studies seem to support the use of this type of device. Such studies, indeed, have been defined as methodologically weak and with no solid theoretical bases [11,12]. In addition, experimental confirmation of the effectiveness of tinted lenses from other laboratories are missing [13].

As an example, a survey has reported improvement in reading rate by using intuitive overlays in a group of patients with suspected or diagnosed specific learning difficulties [14]. Being a ABBA placebo-controlled experiment (i.e. two groups with reversed treatment/placebo administration), the study is expected to provide high degree of evidence. Yet, in our opinion methodological problems and arguable data interpretation make the outcome questionable. First of all, the sample recruited was made of patients showing subjective reduction of their symptoms when using the overlay. Considering the placebo was an ultraviolet blocking filter and the treatment was an overlay accurately chosen by the subject, the real effect of the former as a control treatment looks to be arguable. In other terms, the observer is likely to be aware of which the placebo is and which the device under investigation is, and he/she is expected to be especially motivated when performing the lexical task with the overlay he/she had declared to be helpful, and had thereby previously chosen. However, the average improvement obtained with the overlays was found to be minimal (4%).

In a study recruiting 61 children aged 7-12 years with reading difficulties, Ritchie et al found that colored filters do not improve patients' reading performance [15]. In a subsequent study, the same authors measured reading rate of 18 young poor readers after 1 year of colored filter wearing. Compared with 10 poor readers taken as controls, colored filters did not provide any improvement in reading performance [16]. Palomo- Alvarez and Puell found that 3-months period of wearing yellow filters did not provide any effect in binocular function and reading rate of 46 children (aged 9-11 years) with reading difficulties [17].

Finally, Henderson confirmed that colored overlays do not improve reading rate of dyslexics [18] so that the effect of such devices, if any, should be regarded as a placebo effect [19,20].

Irrespective of the failures reported in the above-mentioned surveys, the idea of specific retinocortical modulation via wavelength selection remains intriguing and worth to be rigorously deepened.

As a matter of fact, two points should be considered:

1-of the two main visual pathways, that is to say the magnocellular (M- or transient) and the parvocellular (P- or sustained) system, the former is supposed to have a major role in reading [21,22,23]

2- there is evidence that long wavelengths suppress the M function.

As a working hypothesis, since convincing evidence has been provided dyslexics to suffer from depressed transient activation, specific colored filters might improve their reading performance by facilitating magnocellular processing via long wavelengths neutralization.

2. The Magnocellular Role in Reading

According to the reading model proposed by Breitmeyer [21], the lexical information is acquired by the parvocellular system during each fixation. And yet, the role of the magnocellular pathway would be crucial, as it acts by inhibiting the sustained (P) activity at the end of each fixation, i.e. after the processing of each letter or syllable has been completed. This way, the M system would trigger the saccadic movement aimed at positioning the next fixation on the subsequent point along the string; such effect is material since it avoids visual persistence, as expected if P cells maintained their activation state beyond the fixation period, that is to say during the saccadic movement.

An alternative model of reading is based on sequential processing of the text provided first by the M, and then by the P-system [22]. M system would be in charge of first orthographic identification, being sensitive to low spatial frequencies (0.37-1.5 cycles/deg [24]), therefore to global analysis. The second stage would be fine details processing, via resolution of higher spatial frequencies (6-12 cycled/deg) performed by the P-system. M-mediated orthographic identification would be the first stage of reading since the transmission of information is faster along the magnocellular network compared to the parvocellular pathway: as a matter of fact, global analysis is accomplished in just 60-80 msec [24]. This way, as reported by Chase and colleagues: "the M channel provides a low spatial frequency visual prime that can be used for orthographic identification. If sufficient information is available, words are identified rapidly on the basis of the M channel alone. However, when the orthographic system fails to identify a word, the system must await for further detailed input from the P channel" [23].

In both models, evidently, the role of the M channel in reading is crucial, and it is indicative that according to a consistent body of literature the magnocellular function is found to be depressed at least in a subgroup of dyslexics (see Aleci, 2013 for a detailed discussion on this topic [25]).

Therefore, if studies could provide evidence transient activation to be impaired by specific light wavelengths (both in normal readers and in dyslexics), their selective absorption via color filters or overlays could help improve the lexical performance of disabled readers. In turn, their transmittance facilitation is expected to depress even more the magnocellular function, further worsening the lexical fluency.

3. The Effect of Wavelength on Transient Activation and Reading Performance

At the basis of color perception are three classes of cones, the S-, M-, and L-cones, sensitive respectively to short (i.e. sensitive to blue, range: 400-500 mn, peak wavelength: 420-440 mn), middle(i.e. sensitive to green, range: 450-530 mn, peak wavelength: 534-555 mn and long wavelengths (i.e. sensitive to red, range: 500-700 mn, peak wavelength: 564-580 mn) [26]. Color perception is the result of the cortical processing of these three retinal output according to an opponent model. In fact, since the range of sensitivity for each class overlaps to a certain amount, recording differences between responses rather than the responses themselves is a more efficient way to gather color information. At the basis of such opponent model is the parvocellular ganglionar system [27]. However, a growing bulk of research suggests the magnocellular system can be affected by wavelengths to a certain extent even if it is blind to colors.

There is evidence, indeed, that red light suppresses M-activation in the lateral geniculate body of monkeys [28,29,30,31]). In humans red light reduces metacontrast [32,33,34] and apparent motion discrimination [32], and increases reaction time to large size (therefore M-mediated) spot-stimuli [35]. In addition, flicker sensitivity is found to be suppressed in presence of a red background (see for example Stromeyer et al [36]). Such effects have been explained as disruptive influence of red light on the magnocellular channels. In turn, high spatial frequency channels (the P system) are found to be mainly sensitive to long wavelength stimuli [37].

Given these premises, it is therefore reasonable to expect wavelength light modulation to affect reading performance, being worsened by red light and, in case, improved after long wavelengths have been removed (improvement with blue light). Indeed, in a paper Chase and colleagues reported some bibliographic evidence that blue light improves reading performance in normal and disabled readers and that red light, in turn, tends to worsen the lexical function [23]. However, the authors highlighted some methodological flaws affecting such studies and reported the results of a series of experiments aimed at clarifying the effect of long and short wavelengths on reading. The authors confirmed that short wavelength transparencies (purple and blue) improve accuracy of normal readers up to 25%, whereas with red filters (that is long wavelengths) reading errors tend to increase. Instead, no effect of color was found on reading rate. Higher accuracy would be due to long wavelength neutralization rather than short wavelength facilitation, in agreement with the theory of the suppressive effect of red light on M-functioning [23].

The ameliorative result of long wavelengths absorption seems to hold also in disabled readers. After three months of blue (but also yellow) filters wearing, slight improvement of lexical performance (increase of 1.5 months more than expected) has been observed in a group of disabled readers (reading age of at least 18 months below the chronological age). In the same experiment intuitive filters did not provide significant advantage [38].

In a double-masked study a consistent reading improvement after wearing blue filters for three months was found in 10% of the patients: the lexical age in these subjects was grown up to 6 months more than in the placebo group [39]. This finding is in line with the better reading comprehension reported in dyslexics under blue illumination more than ten years before by Williams et al [40].

As a counter evidence, in their survey Iovino et al found that blue or red overlays did not increase the reading rate of children with reading disability [41]. It should be recalled, however, that the recruited disabled readers were affected to a certain degree also by attention deficit/hyperactivity disorder. Such comorbidity may have biased the expected outcome.

In summary, the effectiveness of color filters able to retain long wavelengths should be investigated with rigorous and methodologically sound studies, since there is some evidence they could help dyslexics read more accurately. Within the framework of the two cited models of reading, such ameliorative effect could act as follows:

-the reading model proposed by Breitmeyer states M-inhibition prolongs visual persistence time, allowing the processed information from the previous fixation to superimpose on the next one. In this case a blue or purple filter would improve the "sluggish" magnocellular activity, reducing visual persistence time and finally preventing from fixations superimposition.

-the reading model proposed by Chase, in turn, states the transient suppression affects low spatial frequencies, thereby the global orthographic analysis of the words. Placing a filter that retains long wavelengths would relieve such M-inhibition, improving the lexical performance.

Interestingly, the author suggests reading rate of dyslexics could reflect their lexical strategy: in presence of defective M activation, patients who rely upon the magnocellular function are expected to read fast but inaccurately, since on the one hand the global orthographic M-mediated analysis is defective, on the other hand the P system, that could compensate via fine detail analysis of letters and syllables, is not able to keep up with the rapid reading pace, so that the additional information it can provide gets lost.

On the contrary, in dyslexics who learn to rely mostly on the P system, reading would be slower (letter-by-letter) but more accurate.

In the first case, more than in the second, filters stopping long wavelengths would be effective in improving the lexical performance, namely reading accuracy [22].

The fact remains that since the defect has been identified in the M system and M activation is lowered by long wavelengths, a single or at least very limited range of colored filters absorbing selectively long wavelengths are expected to work for every patient, in contrast to the concept of "intuitive" colored filters introduced by Wilkins.

4. Conclusion

In conclusion, in line with what reported by Solan & Richman twenty-five years ago [42], there is no evidence that the rehabilitative model based on the so called" intuitive" colored overlays or filters helps disabled readers read better1. The rehabilitation of dyslexics by means of tinted lenses chosen by the patient is a paradigm without a plausible rational criterion and lacks solid experimental evidence. It is revealing that the choice of the optimum filter is at the discretion of the patient [43,44], and that the estimated number of tests required to find the most suitable color is about one thousand [45]. Still, strict investigations on the effect of wavelength modulation in enhancing the magnocellular function could disclose promising lines of intervention, based on the scientific method rather than on groundless suppositions and anecdotal reports.

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