**The Effect of Spectral Filter Eyeglass Lenses on Adults with ADHD and Irlen Syndrome: Does This Intervention Change the Attention Profile?**

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**Abstract**

Irlen Syndrome (IS), involving difficulty in visual processing, shares symptoms with ADHD. We examine whether spectral filter eyeglasses (SF) improve individuals’ attention profile.

Methods: 39 adults, aged 18–50, diagnosed with ADHD and IS, were fitted with SF, while two control groups were not (n=20\*2). The research tools were an auxiliary tool for ADHD diagnosis—MOXO-CPT(D)—and a DSM-5 ADHD questionnaire.

Results: Significant improvement in attentiveness index was found in the research group. The short-term attentiveness profile changed for 50% of the research group; they displayed no disordered symptoms. In the long-term, 71% changed. Pursuant to using SF, 50% of the research group improved continuous attentiveness with no fatigue, in contrast with control groups.

Conclusions: Perceptible improvement in attentiveness index and change of attention profile among at least 50% of those examined suggests the possibility of ADHD misdiagnosis due to comorbidity with IS, indicating the need to develop differential diagnosis.

**Keywords:** Attention Deficit Hyperactivity Disorder, Irlen Syndrome, spectral-filter lenses, differential diagnosis, reading difficulties, fatigue, continuous attention, comorbidity, specific learning disorders

Throughout our years of experience in research, diagnosis, and treatment of people with Irlen Syndrome (IS), we have encountered many individuals with additional disorders, such as specific learning disorders in reading as well as attention deficit hyperactivity disorder (ADHD). Many of these individuals, after being diagnosed with IS and fitted with spectral filters (SF), experienced an enormous improvement in attentiveness along with improvement in their reading and depth perception, and a decline in headaches and fatigue. Their testimonies prompted us to investigate these two syndromes in an attempt to understand their comorbidity and determine whether differential diagnosis of IS and ADHD can be found.

ADHD, a widely encountered disorder caused by impaired brain functioning, leads to attention difficulties, impulsivity, and hyperactivity. It is common among adults, and its symptoms manifest differently with age (Fletcher, 2014). The onset of symptoms generally occurs by age twelve. Some believe that 2.5% of all adults have been diagnosed with ADHD (Kolodny et al., 2017; López-Pinar et al., 2020; Simon et al., 2009; Vitola et. al., 2017). The prevalence of ADHD among adults has increased over the years (Barkley et al., 2006).

Numerous studies have used brain scans to try to understand the determinants of ADHD and have identified the frontal cortex as the main area of impairment causing ADHD (Dickstein et al., 2006). However, in recent years, studies by means of fMRI have yielded findings that demonstrate impairment in additional areas of the brain. The most recent studies relate to neural networks, which connect various regions of the brain (Hale et al., 2017), rather than focusing on specific areas. A groundbreaking meta-analysis that examined fMRI-facilitated ADHD studies identified the visual variable as a meaningful element in ADHD (Cortese et al., 2012).

Diagnosing ADHD can be difficult, particularly among adults, due to comorbidity with other disorders and phenomena. ADHD displays high comorbidity with learning disorders (DSM-5; American Psychiatric Association [APA], 2013) and other psychiatric disorders (Horning, 1998; Weiss & Hechtman, 1993, p. 408, in Schoechlin & Engel, 2005). In 50%–60% of adult ADHD cases, clinical and psychosocial difficulties are encountered (Knecht et al., 2015; London & Landes, 2016; Young & Goodman, 2016).

Apart from what we know about comorbidity with ADHD, there is evidence that this disorder may be accompanied by secondary effects such as risk-taking, anxiety, psychological disorders, extreme moods, and depression (Schoechlin & Engel, 2005). Among adults, the complexity of identifying ADHD symptoms relative to other illnesses makes it harder to apply differential diagnosis, because the symptoms exhibited by adults are less obvious and specific than they are in children; symptoms tend to be masked by other phenomena (Quintero et al., 2019). Another complicating factor in diagnosing adults is that the adult evaluation questionnaire is based solely on self-reportage, whereas for children additional reports are gathered from teachers and parents. The importance of differential diagnosis of ADHD in adults has implications not only for the quality of life of those affected but bears weighty social and economic implications as well (Knecht et al., 2015; London & Landes, 2016; Young & Goodman, 2016).

Visual processing difficulty underlies IS. This disorder is less familiar but is found in 5%–14% of the population (Bernal & Tosta, 2015; Jeanes et al., 1997; Wilkins et al., 2001) and in 31%–46% of persons with dyslexia (Irlen & Lass, 1989; Kruk et al., 2008). Also known as Meares Irlen syndrome, it was once called Scotopic Sensitivity Syndrome (SSS) (Robinson & Foreman, 1999). In recent years, it has also appeared as Meares Irlen Visual Distress Syndrome (MISVIS) (Chouinard, et al., 2012; Kruk & Sumbler, 2008). In this study, we refer to it as Irlen syndrome (IS). It is characterized by difficulty in visual processing, in other words, how the brain processes what the eyes see. It is usually genetic (Soares & Gontijo, 2016), and symptoms may present in various combinations: sensitivity to light, particularly fluorescent light; difficulty and/or fatigue in reading; trouble with attentiveness; limited field of vision; and trouble with depth perception. This sensitivity may cause sensory regulation problems, stress, headaches and migraines, behavioral issues, learning disorders, and acute fatigue (Barboloni et al., 2009; Belmont, et al., 2000; Huang et al., 2011; Irlen, 1991).

IS is experienced on a spectrum ranging from mild to severe. Its presence (or absence) is determined via a structured protocol in a visual-processing evaluation procedure based, including an assessment of difficulties or fatigue while reading during which the visual-processing problem is confirmed or refuted. Disorders in reading against a white background manifest in distortions such as letters that move, blur, shake, change size, present in three dimensions, and disappear. Personally-fitted SF improve the visibility of the written page and eliminate the distortions that the examinee perceives (Garcia et al., 2018; Robinson & Foreman, 1999; Romera et al., 2019; Wilkins et al., 2001). Studies have shown that colored overlays are more useful for children with dyslexia than for those without (Isla et al., 2005).

Although the precipitant of IS has not yet been explained in scientific terms, it is believed that symptoms are triggered by an overflow of visual information that causes distortions and sensory flooding (Anderson, 2018).[[1]](#footnote-1) The treatment for people with IS involves being fitting with colored overlays for reading as a partial and immediate solution and with SF lenses as a complete, long-term solution. These accessories improve visual processing by filtering out specific wavelengths that cause disturbances and distortions (Garcia et al., 2018; Guimaraes et al., 2019; Irlen, 1991; O’Connor et al., 1990).

**The ADHD–IS Nexus**

Loew and Watson (2013) were the pioneers who investigated the connection between IS and ADHD and probed the similarities of their symptoms. They also examined the frequency of IS characteristics among individuals diagnosed with ADHD. Seventy-six people took part in their study: 12 diagnosed with ADHD, 18 with IS, and 46 in a control group in which neither syndrome was present. The participants were asked to fill in a nine-item questionnaire. Each item presented a common characteristic of IS, such as slow reading, fatigue or difficulty in reading, losing one’s place while reading, sensitivity to light, and clumsiness. The participants were asked to state whether they had these characteristics or not. Among participants who had been diagnosed with ADHD, the rate of affirmative answers to these questions ranged from 50% to 83% in seven of nine IS characteristics. The findings showed significant lack of variance between the ADHD group and the IS group and strongly significant variance between those diagnosed with ADHD and members of the control group.

Another link between IS and ADHD is found in the determinants of these disorders. It appears that it is not only IS that originates in faulty visual processing; studies in recent years by means of fMRI also attest to visual disorders among people with ADHD. For example, Hale et al. (2014) found that the right lobe of persons with ADHD showed significant reduction of visual brain activity compared with control subjects, causing defective visual processing in performing the top-down task of identifying letters and their location. According to Hale et al., children with ADHD neglect task outcomes before completion due to reduced activation processing across visual networks in their brains. In another study, this time among adults with ADHD, brain activity pointed to neurological functioning in both the frontal network and in visual system subserving visuospatial (working) memory and attention (Hart et al., 2013). Therefore, in the opinion of Hart et al., visual tasks should play no less a role than verbal tasks in ADHD evaluation of adults (Lin & Shur Fen Gau, 2020). Another visual aspect that relates to coordination of eye effort was investigated by Jiménez et al. (2020), who found a high frequency of poor oculomotor control in an attention-related task among persons diagnosed with ADHD. They posit that this may suggest another stratum in the evaluation of children and adults with ADHD.

In the research literature, a connection between the two syndromes is found in both the similarity of symptoms and the visual element. We wish to examine this nexus in light of the equivocal nature of ADHD diagnosis, particularly among adults, and the fact that there is not currently a process of differential diagnosis between the two syndromes. In this study, we wish to determine whether SF lenses that condition a response to IS may improve one’s attention profile. There may be two possibilities:

1. There are people who have both IS and ADHD, as a comorbidity or as an accompanying attention disorder.
2. There are people with IS who have been misdiagnosed with ADHD.

**The Research Questions**

Could the use of personally-fitted SF improve the attention profile of people aged 18–50 who find reading difficult or tiresome and have been diagnosed with both ADHD and IS?

If the answer is yes, then:

1. Is this improvement significant in each measure of attention (continuous attention, specificity of inattention, impulsivity and hyperactivity)?
2. Can the improvement be so significant as to converge those examined into the norm in terms of attention functioning and, if so, what differential diagnosis may exist between the disorders?
3. Does using SF mitigate fatigue in activity that requires continuous attention among these persons, and to what extent?

**Hypotheses**

1. Some members of the research group will show meaningful long- and short-term attention improvement after using personally-fitted SF lenses.
2. Some of the improvement in their attention will manifest in a change in attention profile and convergence into the normal range. A similar tendency will present with both tools, in both the short and the long terms.
3. SF use will mitigate fatigue among research participants with IS who wear SF eyeglasses (R) relative to members of the non-intervention control group (AI) in continuous-attention testing.

**Method**

**Research Population**

R – a research group comprising 39 participants diagnosed with both ADHD and IS who were specially fitted with SF eyeglass lenses;

AI – a control group comprised of 20 participants diagnosed with ADHD and IS who were not specially fitted with SF eyeglass lenses;

XX – a control group comprised of twenty neurotypical participants, i.e., without ADHD and without IS.

**Research Tools**

Two tools were used to test the participants’ attention: one for the short term, MOXO (CPT-D), a digital test that is valid for the detection of attention symptoms, and one for the long term: the DSM-5 diagnostic questionnaire.

**Pre-Diagnosis Research Tools**

1. An IS filtering questionnaire: a pre-diagnosis questionnaire that determines whether symptoms that may justify a positive diagnosis are present. The questionnaire items relate to light sensitivity, reading, writing, working at a computer, reading musical notation, sports, driving, and attention and spatial-orientation ability. If at least three affirmative answers are given in three or more categories, evaluation is recommended.[[2]](#footnote-2)
2. The DSM-5 test for adults—administered twice, once for filtering purposes and once to check long-term outcomes.

 The attention and concentration disorder evaluation test is taken from the *Diagnostic and Statistical Manual of Mental Disorders (*DSM-5)*,* published by the American Psychiatric Association (2013), for evaluation and statistics of psychological disorders. It is the Western world’s standard for defining psychiatric diagnoses. The ADHD questionnaire is divided into two parts. The first relates to the variable of inattention and the second to variables of hyperactivity and impulsivity. Each part is comprised of nine items that relate to behavioral characteristics. Participants answer in the affirmative to each question that presents a behavior that is typical of them. If an adult participant answers in the affirmative to five or more of the nine items, diagnosis of a disorder is supported, provided these behavioral symptoms / characteristics have presented in the half-year preceding the completion of the questionnaire.

**Research Tools in the Diagnosis Stage**

1. IRPS—the Irlen Reading Perceptual Scale (Irlen, 2018)—is used to evaluate reading problems and select an optimum spectral overlay. It is divided into three sections. Section 1 has two scales :(1) a Reading Difficulty Questionnaire that investigates reading problems such as skipping lines, misreading words, and poor comprehension, and (2) a Reading Discomfort Questionnaire that tests for perceptual or physical disturbances while reading, such as eye strain, fatigue, and headache. Section 2 involves different visual tasks with high-contrast images designed to increase visual stress in order to allow greater precision in choosing optimum spectral overlays (ten different colors of the Irlen Spectral Overlays set). Participants are asked if they presented symptoms of visual stress and/or perceptual distortions during and after each visual task. In Section 3, there is an assessment of the extent to which the use of colored plastic overlays improved the performance of these visual tasks and of reading (Noble et al., 2004).

Studies on the validity of the IRPS Manual (Robinson et al., 1995; Tyrrell et al., 1995) found significant score differences in all sections of the manual between reading-disabled and normally achieving students. Gray (1999) reported high internal validity for subsections of the IRPS Manual as well as significant relations between manual scores and standardized measures of reading achievement, spelling achievement, and visual processing. High retest reliability for color preferences in colored overlays was reported as well )Jeanes, et al.,1997; Wilkins, 2001); the preferences were far more consistent than could reasonably be expected on the basis of chance alone. Kruk et al. (2008) showed a relation between the IRPS and perceptual processing.

1. The Irlen Differential Perceptual Schedule (IDPS) is used for evaluation and fitting of SF. By means of this test, the optimal combination of lens colors is chosen from a set of colored eyeglass lenses. The fitting allows the participant to see what is written on and around the page without distortions and disturbances. Participants ascertain the accuracy of SF fit by answering questionnaire items and test the quality of their performance by performing visual tasks on paper and in space while wearing SF, with the outcomes compared with performance of the same tasks without SF (Irlen, 1988).
2. MOXO: CPT(D)—a tool for attention-profile assessment, tested by Berger and Goldzweig (2010) and found to have 89.9% sensitivity and 86.1% specificity (MOXO Professional Guide, 2017). Used in various international studies (Berger & Cassuto, 2014; Borkowska, 2016; Grossman et al., 2015), it compares examinee outcomes relative to those of a neurotypical group by age and sex. Four attention indicators are tested: attention, specificity of inattention, impulsivity, and hyperactivity. The test allows achievements to be compared at two points in time—at the beginning of the test and at its end—in order to examine the extent of fatigue in a task that requires continuous attention.

The adult version of this test (ages 13–70) was used. During this test, each time the target picture appears on the screen, the examinee is asked to press the space key one time, as quickly as possible. The pictures are shown in various stages, at varying paces and loads, and along with visual, audial, and combined distractors. This task requires continuous attention and use of judgment in regard to the target picture. At each stage, the system measures the examinee’s performance as described below. The raw performance scores for the various measures are converted into standard scores as required and are compared with the neurotypical control group’s performance on the test, divided by age and gender. A standard score below -1.65 represents a 5% deviation from the accepted norm among the population. Deviation in at least one measure is indicative of suspected ADHD.

The participant’s initial score is 100. The criteria used to calculate the final score are different for each measure:

**Attention:** correct identification of the target picture and exactly the requisite response. For no response or a wrong response, eight points are subtracted.

**Specificity of inattention:** response time is measured after the picture appears on the screen. For each response not performed in time, four points are subtracted.

**Impulsivity:** erroneous keystrokes due to a premature response. For each erroneous keystroke, ten points are subtracted.

**Hyperactivity:** unnecessary keystrokes. For each unnecessary keystroke, ten points are subtracted.

The test assesses the extent of fatigue over time by calculating differences in performance between the first stage and the last. Both stages are identical in terms of task, without distracting elements. A decline in achievements at the end of the test relative to performance at the beginning is indicative of fatigue. To test the extent of fatigue, the participant’s raw scores on the various measures are used and a decline of more than ten points in performance on one or more measures is classified as difficulty in maintaining continuous attention, i.e., fatigue.

**After 3–6 Months**

The DSM-5 questionnaire was filled out again by the research group after its members wore SF in the intervening period of 3-6 months.

**Research Procedure**

**Choosing the Research Population**

The final population chosen was comprised of 79 adults aged 18–50.

Research ethics—the research proposal was presented to the institutional ethics committee of David Yellin College of Education and was approved by the head of the college’s research authority.

In Stage 1, a search was conducted for adults who had been diagnosed with ADHD prior to the study by a neurologist or a psychiatrist, and who also have difficulties and/or fatigue in reading (a typical symptom of IS). The search took place by means of DSM-5 filtering questionnaires, Irlen’s initial filtering questionnaire, and a MOXO test. All candidates who were not found by the MOXO test to have ADHD, with 10% sensitivity, were filtered out. The test identified only 89.9% of cases as TP (Berger & Goldzweig, 2010; MOXO Professional Guide, 2017).

In Stage 2, suitable participants took an IRPS evaluation to make sure they indeed suffer from IS.

In Stage 3, those in the research group were personally fitted with SF by means of the IDPS diagnostic tool. (In the course of this evaluation, one of the 40 people who cleared the initial filterings was filtered out because his SF did not alleviate his IS symptoms.)

In Stage 4, the research group took the MOXO test twice in one day—once without SF and again, an hour later, wearing SF for the first time. Those in the control groups (XX and AI) took the test on two occasions one hour apart, without any intervention.

In the fifth and final stage, those in the research group filled in the DSM-5 questionnaire again after wearing SF for 3–6 months.

**Findings**

**Improvement in Short-Term Performance—Effect of the Intervention on Performance in Attention Measures on the MOXO Test**

To test for differences in performance of the attention measures (attention, specificity of inattention, impulsivity, and hyperactivity) pursuant to SF use and to determine whether these differences differ among the three groups examined (R, AI, XX), four repeat bidirectional measurement analyses were performed, one for each measure. The independent variables in each of the four analyses were (1) time: pre-intervention and post-intervention (within-subject), 2) group—the research group, which wore SF (R), a control group without SF (AI), and a neurotypical control group (XX) (between-subject). The dependent variable in each analysis was the performance of each attention measure. The findings are described below.

**Attention.** Time was found to have a significant effect: F(1,76)=10.81, p<.01, ɳ2= 0.12. Namely, the attention performance of all three groups was better on the second test than on the first: R = -1.22, SD=2.93), with the intervention performed on the research group (M= -0.44, SD=2.19).

Furthermore, a significant time\*group interaction was found: F(2,76)= 5.66, p<.01, ɳ2= 0.13. To test for the source of the interaction, a t test for dependent samples was performed for each group separately. Here it was found that the improvement on the second test was significant among the research group—t(38)= 4.26, p<.001—as against the control group without SF, t(19)= .26, p>.05, and the XX control group, t(19)= 0.99, p>.05. No significant improvement took place on the second test. (See Table 1 and Figure 1.)

Table 1. *Means and SDs of Attention Measures by Time and Group*

|  |  |  |
| --- | --- | --- |
| Group | Pre-intervention | Post-intervention |
|  | M | SD | M | SD |
| R | -1.76 | 3.38 | -0.39 | 1.97 |
| AI | -1.47 | 3.10 | -1.22 | 3.24 |
| XX | 0.09 | 0.66 | 0.26 | 0.57 |

Figure 1. *Visual Presentation of Interaction in Attention Measure Before and After Intervention, by Group*

**Specificity of inattention.** Time was found to have a significant effect: F(1,76)=32.06, p<.001, ɳ2= 0.30. Namely, the specificity of inattention of the three groups was better post-intervention (M= -1.70, SD=2.42) than pre-intervention (M= -2.95, SD=2.70).

Also, a significant time\*group interaction was found: F(2,76)= 4.68, p<.05, ɳ2= 0.11. To test for its origin, a t test for dependent samples was performed for each group separately, and it was found that both the research group— t(38)= 5.21, p<.001—and the control group— t(19)= 3.10, p<.01—improved their inattention measure between Measurement 1 and Measurement 2. When a Cohen’s d test was used to check for size of effect, the improvement effect was found to be greater among the R group (d=0.82) than among the AI group (d=0.68). Control group XX was found to have the largest effect (d=1.0) (Table 2, Figure 2).

Table 2. *Means and SDs of Inattention Measures by Time (Post-Intervention) and Group*

|  |  |  |
| --- | --- | --- |
| Group | Pre-intervention | Post-intervention |
|  | M | SD | M | SD |
| R | -3.50 | 2.86 | -1.71 | 2.31 |
| AI | -3.51 | 2.77 | -3.03 | 2.74 |
| XX | 1.29 | 1.40 | -0.33 | 1.40 |

Figure 2. *Visual Presentation of Interaction in Attention Measure before and after Intervention, by Group*

**Impulsivity and hyperactivity.** Time was found to have a significant effect. Namely, the extent of impulsivity and hyperactivity among the three groups was lower in Measurement 2 than in Measurement 1, meaning that their performance was better (fewer errors occasioned by premature responses and overresponses).

Impulsivity: F(1,76)=6.77, p<.05, ɳ2= 0.08 in Measurement 1 and a lower outcome, M= 0.28, SD=2.88, in Measurement 2 (M= -0.60, SD=4.05). However, no significant time\*group interaction was found in the impulsivity measure: F(2,76)=2.68, p>.05, ɳ2= 0.07.

Hyperactivity: F(1,76)=13.74, p<.001, ɳ2= 0.15 in Measurement 2 (M= 0.22, SD=1.39), as against M= -0.71, SD=2.09) in Measurement 1. In this measure, a significant time\*group interaction was found: F(2,76)=3.12, p=.05, ɳ2= 0.08. To determine its source, a t test for dependent samples was performed for each group separately. Here it was found that in both the research group (R, t(38)= 3.93, p<.001) and the neurotypical control group (XX, t(19)= 2.65, p<.05) the hyperactivity measure showed improvement between Measurement 1 and Measurement 2. Among the control group that did not use SF (AI), no significant differences between the measurements were found: t(19)= 1.80, p>.05.

**Improvement in Long-Term Performance—According to the DSM-5 Questionnaire**

This section presents the responses of 35 members of the research group to the DSM-5 self-reportage questionnaire. The results pertain to the first and second research questions—this time, however, relating to the long term.

To determine whether pre-SF / post-SF differences exist in the mean of the two parts of the questionnaire, a t test for dependent samples was performed for each part of the questionnaire.

In reference to the inattention measures, the analysis found significant differences in the means between the measurements: t(35)= 10.36, p<.001. The mean number of questions answered in the affirmative for measures of inattention (M=6.23, SD=1.44) was higher pre-SF than post-SF (M=6.23, SD=1.44). (As noted, fewer than five affirmative responses are indicative of no suspicion of ADHD.)

As for the impulsivity and hyperactivity measures, the analysis turned up significant differences in means between the measurements: t(34)= 5.80, p<.001. The pre-SF impulsivity and hyperactivity mean (M=4.20, SD=2.45) exceeded the post-SF mean (M=2.14, SD=1.65).

To check for the measures in which the improvement was greatest, Cohen’s d was calculated to test the size of the effect in improving each part of the questionnaire. The measures obtained were d = 2.2 for inattention and d = 1 for hyperactivity/impulsivity. Accordingly, the difference between “pre” and “post” is large in both measures but larger in the inattention measure.

**Findings Comporting with Hypothesis 2**

**Change in Attention Profile—Short-Term Attention Measure**

The change in attention profile between the measurements among those tested for IS was examined. In the analysis, it was found that 49% of the research group (R) showed improvement in their attention profile after the intervention. Namely, the attention profiles of 19 of 39 members of this group transitioned from indication of attention and concentration disorder to the bounds of the normal. By comparison, only 20% of the persons in control group XX who were checked (four of 20) exhibited a change in their attention profile in Measurement 2.

**Change in Attention Profile—Long-Term**

The findings show that 71.4% of the research group saw a change in their attention profile after long-term SF use, as against 26% whose hyperactivity/impulsivity profile changed. (In this study, only 43% of persons checked reported in advance that they had been diagnosed with hyperactivity/impulsivity.)

Table 3. *Means of Affirmative Answers to Questions on DSM-5 by Members of Research Group (R) regarding Inattention and Hyperactivity/Impulsivity before and after SF Use*

|  |  |  |
| --- | --- | --- |
| Sections of questionnaire | First reportage | Second reportage (post-intervention) |
| Inattention | 6.23 | 2.88 |
| Hyperactivity/impulsivity | 4.2 | 2.14 |

Figure 3. *Means of Affirmative Answers to Questions on DSM-5 by Members of Research Group (R) regarding Inattention and Hyperactivity/Impulsivity before and after SF Use*

**Findings Comporting with Hypothesis 3**

**Inter-Group Differences in Extent of Fatigue and Difficulty in Maintaining Continuous Attention**

In this section, we used a chi-square test to examine differences among the groups (R, AI, XX) in the extent of their fatigue. To determine the extent of fatigue, two measurements were taken: at the beginning of the test and at the end. For the analysis, the participants were divided into two groups: those who suffered from fatigue in at least one measure of attention at the end of the test, and those who did not. The differences were tested at two points in time: before the research group underwent the intervention, and after.

The analysis shows that there was no connection between group and extent of fatigue before the intervention: (2)=4.65, p>.05. Namely, no statistically significant difference was found and the differences were relevant for the sample but cannot be scaled to the entire population. In the second test, after the research group underwent the intervention, significant differences among the groups in terms of fatigue level were found: (2)=46.99, p<.001. We found that 100% of participants in groups AI and XX experienced fatigue in at least one measure as against 25.6% of participants in the research group (R)—very close to the “pre” situation of the neurotypical control group (XX).

Table 4. *Continuous Attention: Decrease in Performance at End of Test Relative to Beginning in at least One Measure, by Groups*

|  |  |  |
| --- | --- | --- |
| Group | Test 1 | Test 2 |
|  |  | % |  | % |
| R | 21 | 53.8 | 10 | 25.6 |
| AI | 10 | 50 | 20 | 100 |
| XX | 5 | 25 | 20 | 100 |

Figure 4. *Continuous Attention: Percent Showing Fatigue in at Least One Measure after Tests 1 and 2, by Groups*



Subsequently, we wished to probe the findings in greater depth and check the extent of fatigue in each measure separately by testing for inter-group differences in the extent of change in performance between the beginning and the end of the test in Measurement 2, i.e., after the research group underwent the intervention. A repeat bidirectional measurement analysis was performed for each attention measure in which the independent variables were time—beginning and end of test (within-subject) and group: the SF group (R), the non-SF control group (AI), and control group XX (between-subject). In the variance analyses, no significant time\*group interaction was found for the inattention and hyperactivity/impulsivity measures (p>.05) but a significant time\*group interaction was found in the inattention measure: F(2,76)=8.25, p<.001, ɳ2= 0.18. To test for the source of the interaction, a repeat unidirectional measurement analysis was performed for each group separately. In these analyses, performance was found to have declined in all three groups: research group R: F(1,38)=10.33, p<.01, ɳ2= 0.21; non-SF control group AI: F(1,19)=63.33, p<.001, ɳ2= 0.55; and control group XX: (1,19)=23.39, p<.001,, ɳ2= 0.77. However, the ɳ2 test indicated that the effect was smallest in the research group and largest in the control groups (Table 4 and Figure 4). Thus, members of the control groups experienced much more fatigue than did members of the research group. Notably, a check of inter-group differences in extent of fatigue before the intervention found no significant time\*group interaction: F(2,76)=0.17, p>.05, ɳ2= 0.00. Namely, all three groups experienced similar levels of fatigue in the inattention measure before the intervention.

Table 5. *Means and SDs of Performance on Inattention Measure by Time (Beginning and End of Test) and Group*

|  |  |  |
| --- | --- | --- |
| Group | Beginning of test | End of test |
|  | M | SD | M | SD |
| R | 96.51 | 7.29 | 92.41 | 8.79 |
| AI | 98.00 | 5.73 | 84.00 | 16.62 |
| XX | 100 | .00 | 92.00 | 4.50 |

Figure 5. *Visual Presentation of Time\*Group Interaction in Relation to Extent of Fatigue in Inattention Measure*

**Summary of Outcomes**

In the short term, as proposed in Hypothesis 1, the research group showed significant improvement in the attention measure but not in the inattention, impulsivity, and hyperactivity measures, although the intervention was followed by significant improvement in the hyperactivity measure among the research group as compared with non-intervention among control group AI only. In the long term, comporting with this hypothesis, the attention profile improved on both parts of the questionnaire. Thus, the number of responses that switched from presence of symptoms to no symptoms improved by a factor of two, on average: from 6.23 to 2.88 and from 4.2 to 2.14.

In the short term, Hypothesis 2 was also confirmed: Performance in the inattention measure improved with SF use. Namely, 19 of 39 members of the research group (49%) changed their profiles and converged into the normal range.

This hypothesis is sustained in the long term as well: 71.4 percent of the participants saw changes in their attention profile in the inattention measure after beginning SF use and 25.7 percent of them revised their attention profile in the hyperactivity and impulsivity measure.

As for the large difference between the attention-profile changes in these measures, it is important to note that the pre-SF outcomes in the inattention measure pointed to an attention disorder on average (6.22); several months later, the average profile changed and converged into the normal range (2.88). In Part 2, in contrast, the average profile was already in the normal range in the first questionnaire (fewer than half of the participants reported impulsivity and hyperactivity), among them, too, there was a perceptible improvement in the research group, from 4.2 to 2.14, when the first questionnaire is compared with the second.

As proposed in Hypothesis 3, relating to extent of fatigue, the level of fatigue indeed receded with SF use.

* The level of fatigue in Test 2 was significantly lower in the research group than in the control groups, AI and XX.
* The outcomes point to significant mitigation of fatigue in the inattention measure on the second test among members of the research group as against those in the AI and XX groups—in contrast to the specificity of inattention, impulsivity, and hyperactivity measures, in which no significant difference was found.
* The consistent downward trend of fatigue indicators in the research group while using SF, as against control groups AI and XX, gathered strength in the additional data analyses that we ran with regards to extent of fatigue in at least one measure.

**Discussion**

The point of departure for this study was the similarity of symptoms between ADHD and IS (Loew & Watson, 2013) as well as the underlying issue of visual perception that links these two disorders, a link that is not coincidental. The findings raise several important issues of relevance for adults who are diagnosed with both ADHD and IS, which we addressed in the research hypotheses.

We found the attention measure to be the leading and most significant measure affected by the use of spectral filter overlays, both in the MOXO test for the short term (among the four measures) and, in the long term, in filling in the DSM-5 questionnaire. Among those examined in the research group, around 50% of those diagnosed with ADHD changed their profile in the short term and converged into the normal range. In findings harvested from the long-term reportage as well, some 70% of those tested converged their attention profiles into the normal range. The difference between the long-term and the short-term findings may be rooted in the subjectivity of the long-term reportage, reflecting both the participants’ feelings and feedback they receive from their surroundings. It is also possible that there is a cumulative long-term effect of learning and changing habits. In any event, the attention measure improved significantly with SF use because visual disruptions stopped occurring, allowing examinees to attain a higher level of attention.

Support for this finding, which demonstrates the centrality of the attention measure, appears in Vitola et al. (2017), who, looking into the effects of changes in the transition from DSM-4 to DSM-5 among adults, found the inattention variable in the first part of the questionnaire more dominant in ADHD than the impulsivity and hyperactivity variables in the second part. Our study corroborates this finding and points out the difference between the two parts of the DSM-5 questionnaire. Only 43% of those examined in our study self-reported, at the beginning of the study, that they had hyperactivity and impulsivity disorders on top of attention difficulties.

Further support for our finding of attention as the leading measure emerges in Sibley and Yeguez (2014), who studied adults and found that there are three common characteristics that appear in the first part of the questionnaire (inattention): difficulty in maintaining attention over time, avoiding tasks that entail a continuous attention effort, and difficulty in remaining seated for long periods. These outcomes correspond to those of Loew and Watson (2013), who noticed the similarity of symptoms such as strain and fatigue after sustained reading and difficulty in holding a line of thought in a conversation. Their results correspond to ours in that we found a decline in fatigue. Namely, participants who transitioned to SF use were much more able to maintain continuous attention than were those in the two control groups, all of whom experienced fatigue. The findings of Rogers et al. (2017) correspond to those relating to fatigue in our study, i.e., that adults with ADHD experience significantly more fatigue than the norm.

It follows that the similarity of IS and ADHD in terms of symptoms resides in the continuous-attention measure and is manifested in the extent of fatigue. As a result, is it easy to confuse these two disorders. The question, then, is whether individuals diagnosed with ADHD who find reading difficult and/or tiring may improve their attention and mitigate their fatigue over time by wearing SF. In other words, were they misdiagnosed?

The probability of misdiagnosis of ADHD, especially among adults (in addition to the difficulty of diagnosis due to the resemblance of ADHD to other psychiatric disorders) is also taken up by Sibley et al. (2014) and Marshall et al. (2016), who find a dramatic increase in adult ADHD diagnoses in recent years due to overdiagnosis. Most professional diagnosticians, they claim, diagnose by means of interviews only and believe that, when in doubt, it is better to overdiagnose so that the individuals in question may avail themselves of medication if they find it useful. This approach often leads to misdiagnosis (Marshall et al., 2016).

One may find support for the possibility of misdiagnosis in remarks that participants attached to their responses on the DSM-5 questionnaire. After using SF overlays for several months, they attested that they felt less tired and some willingly renounced the use of attention-enhancing medication.

IS and ADHD may present not only as comorbidities and not only with similar symptoms but also as the result of wrong diagnosis. Our findings, showing strong significance in the measures of attention and continuous attention and high percentages of convergence into the normal range due to SF use, amplify the importance of the results of this study and our argument regarding the probability of misdiagnosis. According to our findings, a process that will lead to differential diagnosis of ADHD and IS is not currently possible, and further research must be conducted on this matter.

We have identified two main limitations in this study. One relates to the relative improvement in performance that occurred among all the groups. In other words, there seems to be some kind of learning effect in the use of the raw data generated by the MOXO tool. The solution that we found involved standardization and effect-size measurement, which sharpened this significant difference in the changes of status between the groups. The second limitation concerns the variance in size among examinees with IS, manifested in the large standard deviations that we found. The explanation for this may relate to the spectrum on which IS presents, from mild to severe. In the future, it may be necessary to bear this parameter in mind.

**Conclusions**

In this study, we examined whether people with ADHD and IS can improve their attention functioning by wearing SF lenses. The results show that around 50% of those diagnosed with both disorders converged into the normal range when they used IS and that some 70% of those tested entered the normal range in the long run. These findings give hope that a large number of people diagnosed with ADHD and IS can avail themselves of SF and thus avoid the need for pharmacological treatment to improve the functioning.

The improvement in attention deficit in particular, in view of our findings in the long term, highlights the magnitude of the change in long-term quality of daily life. Perhaps it takes time for people to digest and internalize all of the changes that occur in their lives when they neutralize visual disruptions by wearing SF.

Another important implication of our results, supported by additional studies, is that SF lenses, for those who need them, also improve quality of life by mitigating fatigue and facilitating sustained attention.

In view of these findings, we recommend adding IS to the diagnostic matrix as a crucial element in the initial process of determining and diagnosing ADHD. Through such a step, it may be found that a person evaluated has ADHD and not IS. However, insofar as IS is found as well, the individual should be fitted with SF lenses because this will strongly improve the likelihood of solving his or her attention problem, or at least mitigate it, with no need for pharmacological intervention. In cases of comorbidity, SF lenses would provide only a partial solution, necessitating continued expert testing for ADHD without the interference of IS symptoms, and treatment accordingly.

Continuing research should be done on the nexus of ADHD and IS. The directions of this research should includea study similar to ours but among children, particularly given the small number of participants in our study with hyperactivity and impulsivity disorder. Moreover, studies by means of fMRI should be carried out in order to find characteristics specific to each syndrome in order to yield clear-cut differential diagnoses.

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