Video Game Vision Syndrome: A New Clinical Picture in Children?

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ABSTRACT

Purpose: To examine a possible relationship between exposure to video games/electronic screens and visual issues in children between 3 and 10 years of age.

Methods: An observational, cross-sectional study of a population of children using video games was employed. All patients between 3 and 10 years of age were recruited at an outpatient unit accredited by the Italian Regional Health Service. Three hundred twenty children (159 boys and 161 girls; mean age = 6.9 ± 2 years) were observed. Ophthalmological examination included assessment of stereoscopic vision on Lang-Stereotests I and II (LANG-STEREOTEST AG, Küsnacht, Switzerland) and identification of the dominant eye using the Dolman method. Furthermore, a questionnaire was used to record asthenopic symptoms and daily exposure to video games and electronic screens. Two groups of children were examined according to the average amount of time spent playing video games daily: children who played video games for less than 30 minutes per day and not every day (control group) and children who played video games for 30 minutes or more every day (video game group). Both groups were then divided into two subgroups: children using other types of electronic screens (eg, televisions, computers, tablets, and smartphones) for less than 3 hours daily (low electronic use subgroup) and children using other types of electronic screens for 3 hours or more per day (high electronic use subgroup).

Results: Asthenopia (especially headache, eyelid tic, transient diplopia, and dizziness), absence of fine stereopsis, and refractive errors were statistically more frequent (mainly in the dominant eye) in children in the video game group.

Conclusions: These symptoms were frequent and peculiar in the video game group and might be part of a video game vision syndrome that has not been defined yet. It is important to recognize these signs as possible functional disorders to avoid erroneous diagnostic and therapeutic interventions.

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INTRODUCTION

Many individuals who spend long periods of time at video display terminals report a combination of eye and vision issues.[1-3] According to the American Optometric Association,[4] computer vision syndrome is "the complex of eye and vision problems related to near work which are experienced during or related to computer use." These symptoms are not exclusively connected to work-related tasks,[5] but can affect individuals of all ages due to the widespread use of video display terminals in everyday life.[6] It has been recently noted that the use of video games can improve the visual performance of adults with amblyopia (spatial resolution of vision, sharpening of amblyopic vision, and enhancement of the contrast sensitivity function).[7,8] A growing num-

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TABLE 1

Sample Characteristics[a]

Patient Distribution	Control Group: Low Electronic Use	Control Group: High Electronic Use	Video Game Group: Low Electronic Use	Video Game Group: High Electronic Use	Total
Total no. of patients	55 (6.6 ± 1.9)	30 (6.3 ± 1.7)	103 (7.0 ± 2.0)	132 (6.9 ± 2.0)	320 (6.9 ± 2.0)
Boys	24 (6.4 ± 2.0)	12 (6.1 ± 1.2)	51 (7.0 ± 2.2)	72 (6.8 ± 2.2)	159 (6.8 ± 2.1)
Girls	31 (6.9 ± 1.9)	18 (6.4 ± 1.9)	52 (7.1 ± 1.9)	60 (7.0 ± 1.9)	161 (7.0 ± 1.9)

control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day; low electronic use subgroup = children who used other electronic screens for less than 3 hours per day; high electronic use subgroup = children who used other electronic screens for 3 hours or more per day

[a]Values are presented as number (mean age [y] ± standard deviation).

ber of children of increasingly younger ages have access to new media (eg, computers, tablets, and video games) for both educational and recreational purposes.[9] Several studies on the development and neuroplasticity of a child's brain[10,11] indicated that temporary alterations of visual functions could arise, primarily in children 10 years of age or younger (a period known as the critical or sensitive period of the visual system) who spend too much time playing video games, both with and without prolonged exposure to other types of electronic screens (eg, televisions, computers, tablets, and smartphones). However, many children seem to ignore issues arising from visual distress most likely due to the adaptability and plasticity of their visual system.[12] Several studies have examined the effect of video display terminals on the adult visual system,[13-17] whereas few studies have been performed on children.[12,18,19] In fact, attention toward the adolescent population has mainly focused on weight[20,21] and behavior.[22,23]

During the past 15 years, in their daily clinical work with children, the authors observed specific findings in younger children that had not been observed in previous generations. The authors hypothesized that the prolonged use of video games could potentially be harmful to the developing visual systems of children. The aim of the current study was to examine a possible relationship between certain visual issues in children and their exposure to video games and electronic screens.

PATIENTS AND METHODS

Sample

This observational, cross-sectional study was performed in an outpatient unit accredited by the Italian Regional Health Service and run by Dr. Rechichi. All healthy children between 3 and 10 years of age who attended the eye clinic between the beginning of 2012 and the end of 2013, either for routine examination or due to visual symptoms, were recruited. Exclusion criteria were congenital or acquired syndromes (eg, delays in mental development or severe hyperactivity) and eye diseases that cause alterations of the ocular surface or reduced visual acuity (eg, uveitis or albinism).

The authors considered the ethical aspects of the study and followed the guidelines of the tenets of the Declaration of Helsinki. The study was approved by the institutional review board of the Department of Experimental Medical-Surgical Sciences of Messina University, Italy, and a signed informed consent form was obtained from the parents.

The sample comprised 320 children (159 boys, 161 girls; mean age: 6.9 ± 2 years) who were examined by only one pediatric ophthalmologist (CR) using the same instruments (**Table 1**). The lower age limit of 3 years was chosen because this is the typical period when children start playing video games and using other electronic screens[24] and the upper age limit of 10 years was chosen because the visual system of children is highly dynamic during the critical period and up to this age.

Tests Performed

All patients underwent both ophthalmological and orthoptic examinations, and physiological, pathological, and ophthalmological histories were obtained from the parents. The orthoptic evaluation included ocular motility, identification of the dominant eye using the Dolman method,[25] cover test for distance and near vision using the Lang Fixation Cube (LANG-STEREOTEST AG, Küsnacht, Switzerland) as a target for near fixation, and the 4 prism diopter base-out test.[26] Stereopsis was tested with Lang-Stereotests I and II (LANG-STEREOTEST AG).[27]

The Lang-Stereotest is an easy-to-use test that uses random dots[28] and cylinder gratings for image separation and is designed for the screening of stereoscopic vision in children. Two versions of the test plates, which differ only according to the three-dimensional objects to be recognized, are available. The Lang-Stereotest I displays a cat (disparity of 1,200 seconds of arc), a star (600 seconds of arc), and a car (550 seconds of arc), whereas the Lang-Stereotest II displays an elephant (600 seconds of arc), a moon (200 seconds of arc), and a truck (400 seconds of arc). In addition, the Lang-Stereotest II contains a star (200 seconds of arc) that can be viewed with one eye only.

When viewed monocularly, these tests do not provide clues regarding form aside from the star in the Lang-Stereotest II, whereas each stereoscopic form can be recognized binocularly. In contrast to most random-dot tests requiring red–green or polarized glasses, the images of the two eyes in the Lang-Stereotests are separated by a system of fine parallel cylindrical stripes (ie, a lenticular screen). Beneath each cylinder, there are two fine layers of pictures, one seen by the right eye and the other by the left eye. This has two advantages in that no glasses are necessary and the eye movements of younger children can be easily observed.

During examination, the examiner sits opposite the child to observe the eye movements more easily. The test plate is shown exactly at right angles and a distance of approximately 40 cm (16 inches). The child is asked whether he or she can see anything on the plate and the searching movements of the eyes are observed. When a three-dimensional object has been detected, the child is asked to look for additional objects and describe them. The child may then also point at the figures and should be able to determine which of them stands out the most. The possible results for Lang-Stereotests I and II are positive (correct localization and naming of two of the three hidden objects), negative (no object can be detected), and doubtful (only one hidden object is localized and named correctly).

Assessment of refraction was performed using the KR8100P autorefractometer (Topcon Corporation, Tokyo, Japan) by taking at least five measurements for each eye before the evaluation of subjective monocular visual acuity with optotypes at a distance of 3 m in both non-cycloplegic and cycloplegic conditions. Cycloplegia was obtained by cyclopentolate drops (1%) administered twice at an interval of 10 minutes. Astigmatism was defined as any refractive error with a cylindrical component of ±0.50 diopters or more. Any non-accommodated eye requiring correction with a spherical component of +0.50 diopters or more to reach 10/10 was defined as hypermetropic. The study of ocular surface and anterior segment was performed with the SL-3E Slit Lamp (Topcon Corporation) and the examination of the fundus by direct (Miroflex H2; Heine USA, Ltd., Dover, NH) and indirect (Sigma 150; Heine USA, Ltd.) ophthalmoscopy.

After the ophthalmologic examination, a questionnaire was used to collect the following information from the parents: the child's estimated average time spent playing video games (less than 30 minutes and not every day or 30 minutes or more every day), estimated average daily time spent using other types of electronic screens (less than 3 hours per day or 3 hours or more per day), and any asthenopic symptoms (ie, burning, blurred vision, ocular dryness, tearing, eye strain, eye ache, transient diplopia, dizziness, headache, and eyelid tic).

Patients were then divided into two groups: children who played video games for 30 minutes or more every day (video game group) and children who played video games for less than 30 minutes per day and not every day (control group). Both groups were then divided into two subgroups: children who used other types of electronic screens for less than 3 hours daily (low electronic use subgroup) and children who used other types of electronic screens for 3 hours or more per day (high electronic use subgroup) (**Table 1**).

The data obtained were collected and stored in a computer database (Excel 2013; Microsoft Corporation, Redmond, WA).

Statistical Analysis

The chi-square test was used for comparison and a *P* value of less than .05 was considered statistically significant. For statistical analysis, due to the low number of patients with phoria, patients affected by esophoria and exophoria were combined into a single group (heterophoria) because a functional imbalance of the eye muscles is typical

TABLE 2

Daily Time Spent Playing Video Games and Prevalence of Asthenopic Symptoms

Asthenopic Symptoms	Control Group (n = 23)	Video Game Group (n = 136)
No. of symptoms reported by patients	28	183
Headache	12	73
Burning	8	41
Eye strain	3	17
Eyelid tic	1	16
Blurring	3	9
Transient diplopia	0	11
Dizziness	0	9
Eyeache	1	7
Ocular dryness	0	0
Tearing	0	0

control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day

for both phorias. For statistical analysis of stereopsis, the children with doubtful and negative results on the Lang-Stereotests were combined into a single group (Lang negative).

RESULTS

Asthenopia

Of the 320 patients, 49.7% (23 in the control group and 136 in the video game group) reported at least one symptom of asthenopia. Of these, 26.6% (85 patients) suffered from headaches and 3.4% suffered from transient diplopia. Furthermore, eyelid tic was present in 5.3% of patients and 2.8% reported dizziness (**Table 2**).

When separating the patients according to time spent playing video games, 85.5% of the video game group had asthenopia ($P < .001$) compared to the control group. The comparison between the low electronic use subgroups within the control and video game groups showed a higher prevalence of asthenopia in the video game group ($P < .0001$), whereas the comparison between the high electronic use subgroups within both groups was not statistically significant because there was also a high prevalence of asthenopia in the high electronic use subgroup of the control group (**Table 3**).

Stereopsis

Of the 320 patients included in the study, 6 had microtropia according to Lang[29] and were excluded from the statistical analysis of stereopsis. Considering all remaining patients (n = 314), 70.7% had stereopsis on the Lang-Stereotest I and 77.1% had stereopsis on the Lang-Stereotest II. When separating the patients according to their use of video games, the video game group showed a significantly lower percentage of stereopsis (62.3% positive on the Lang-Stereotest I, 71.0% positive on the Lang-Stereotest II) in comparison to the control group (94.0% positive on both Lang-Stereotests I and II) ($P < .0001$ for both Lang-Stereotests I and II). A comparison of the low and high electronic use subgroups within both the control and video game groups showed no statistically significant difference. The comparison between the control and video

TABLE 3

Relationship Between Time Spent on Video Games and Other Electronic Screens and Asthenopia

Presence of at Least One Symptom of Athenopia	Low Electronic Use	High Electronic Use	Total
Control group	7	16	23
Video game group	60[a,b]	76[a,c]	136

low electronic use subgroup = children who used other electronic screens for less than 3 hours per day; high electronic use subgroup = children who used other electronic screens for 3 hours or more per day; control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day

[a] $P < .001$ for the video game group versus the control group.

[b] $P < .0001$ for the video game group versus the control group in the low electronic use subgroup.

[c] No significance for the video game group versus the control group in the high electronic use subgroup.

TABLE 4

Clinical Features and Time Spent on Video Games and Other Electronic Screens

	Control Group		Video Game Group	
Feature	**Low Electronic Use**	**High Electronic Use**	**Low Electronic Use**	**High Electronic Use**
Stereopsis				
Lang-Stereotest I positive	53	25	62[a]	82[a]
Lang-Stereotest I negative	2	3	40[b]	47[c]
Lang-Stereotest II positive	53	25	73[d,e]	91[d,e]
Lang-Stereotest II negative	2	3	29[b]	38[c]
Tropia				
Esotropia	0	2	1	3
Phoria				
Orthophoria	53	25	72	107
Heterophoria	2	3	30[f,g]	22[f]
Esophoria	0	1	13	13
Exophoria	2	2	17	9

control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day; low electronic use subgroup = children who used other electronic screens for less than 3 hours per day; high electronic use subgroup = children who used other electronic screens for 3 hours or more per day

[a]$P < .0001$ for the video game group versus the control group for Lang-Stereotest I.

[b]$P < .0001$ for the video game group versus the control group for Lang-Stereotests I and II in the low electronic use subgroup.

[c]$P < .01$ for the video game group versus the control group for Lang-Stereotests I and II in the high electronic use subgroup.

[d]$P < .0001$ for the video game group versus the control group for Lang-Stereotest II.

[e]$P < .05$ for Lang-Stereotest I versus Lang-Stereotest II in the video game group.

[f]$P < .001$ for heterophoria in the video game group versus the control group.

[g]$P < .0001$ for heterophoria in the video game group versus the control group in the low electronic use subgroup.

The Lang-Stereotests I and II are manufactured by LANG-STEREOTEST AG, Küsnacht, Switzerland.

game groups showed for both the low and high electronic use subgroups that the results of Lang-Stereotests I and II were significantly worse in the video game group. Moreover, the results obtained for Lang-Stereotests I and II in the low and high electronic use subgroups within the control group were exactly the same, whereas there was a statistically significant difference for both tests in the video game group ($P < .05$) (**Table 4**).

Phoria

Only 18.2% of patients had heterophoria. Of these, 47.4% had esophoria and 52.6% had exophoria. The video game group showed a higher prevalence of heterophoria (22.5%) compared to the control group (6.0%) ($P < .001$). Additionally, when considering the low electronic use subgroup, the video game group showed a significantly higher prevalence of heterophoria compared to the control group ($P < .0001$) (**Table 4**).

Refraction

The video game group had a higher prevalence of ametropic eyes compared to the control group (90.4% vs 51.8% of eyes, respectively; $P < .0001$), which remained when the low and high electronic use subgroups were considered. Furthermore, the video game group had a higher prevalence of astigmatism than the control group (58.5% vs 20.0% of eyes, respectively; $P < .001$). In the control group (170 eyes), the high electronic use subgroup (35.3% of eyes) showed a significantly higher prevalence of hyperopia (41.7% vs 24.5% of eyes, respectively; $P < .001$) and astigmatism (35% vs 11.8% of eyes, respectively; $P < .001$) compared to the low electronic use subgroup (**Table 5**). Moreover, nearly all children in the study required the same correction, in both non-cycloplegic and cycloplegic conditions.

Dominant Eye

Regarding refraction in the dominant eye, a prevalence of 83.1% of refractive error was observed

TABLE 5

Refraction and Time Spent on Video Games and Other Electronic Screens

Refraction	Control Group (170 Eyes) Low Electronic Use (110 Eyes)	Control Group (170 Eyes) High Electronic Use (60 Eyes)	Video Game Group (470 Eyes) Low Electronic Use (206 Eyes)	Video Game Group (470 Eyes) High Electronic Use (264 Eyes)	Total
Emmetropia	70	12	18	27	127
Ametropia	40	46	176[a,b]	219[a,b]	481
Hyperopia	27	25[c]	56	64	172
Myopia	0	2	12	18	32
Mild (≤ 3.00 D)	0	2	11	18	31
Intermediate (< 3.00 to ≤ 8.00 D)	0	0	1	0	1
Pathologic (> 8.00 D)	0	0	0	0	0
Astigmatism	13	21[d]	120[e]	155[e]	309
With-the-rule	8	17	86	120	231
Against-the-rule	3	0	10	17	30
Oblique	2	4	24	18	48

control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day; low electronic use subgroup = children who used other electronic screens for less than 3 hours per day; high electronic use subgroup = children who used other electronic screens for 3 hours or more per day; D = diopters

[a] $P < .0001$ for the prevalence of ametropic eyes in the video game group versus the control group.

[b] $P < .0001$ for the prevalence of ametropic eyes in the video game group versus the control group for both the low and high electronic use subgroups.

[c] $P < .001$ for the prevalence of hyperopia in the high electronic use subgroup versus the low electronic use subgroup for the control group.

[d] $P < .001$ for the prevalence of astigmatism in the high electronic use subgroup versus the low electronic use subgroup for the control group.

[e] $P < .001$ for the prevalence of astigmatism in the video game group versus the control group.

for the whole sample. In the video game group, a higher prevalence of refractive error was found in the dominant eye than in the non-dominant eye ($P < .001$). Among the refractive errors, astigmatism had a higher prevalence in the dominant than in the non-dominant eye ($P < .001$). Such differences between dominant and non-dominant eyes were not found in the control group (**Table 6**).

DISCUSSION

Recently, there has been a sharp increase in the number of children spending long periods of time using video games in addition to other types of electronic screens.[9] The number of video games and the possibility of using them on laptops, large television screens, or smaller devices such as tablets or pocket-size smartphones has never been as great as it is today and these games have become accessible to almost every child in modern societies.

Despite its observational character, the current cross-sectional study suggests that prolonged use of video games for 30 minutes or more almost every day in children up to 10 years of age might affect and compromise the development of their visual pathways. Could this complexity of symptoms be defined as a video game vision syndrome, similar to computer vision syndrome in adults, yet with some different features? Could the appearance of the highlighted symptoms in children playing video games be explained as the consequence of an excessive effort and a particular, fast, detailed performance of the still plastic visual system? Could the task of video gaming cause symptoms of both asthenopia and temporary cortical suppression of the non-dominant eye by mainly eliciting the monocular pathways of the dominant eye? The following observations might answer these questions.

First, symptoms of asthenopia were common, mainly in the video game group. Among all reported symptoms, the most frequent was headaches, although with different characteristics from headaches reported in computer vision syndrome. Whereas adults reported headaches at work, most children in this study did not complain of headaches while playing video games. Conversely, the patterns of headaches reported from children ranged from sudden attacks with sharp and acute pain that caused emergency situations for parents and pe-

TABLE 6

Refraction in the Dominant and Non-dominant Eye and Time Spent on Video Games and Other Electronic Screens

Refraction	Control Group: Low Electronic Use	Control Group: High Electronic Use	Video Game Group: Low Electronic Use	Video Game Group: High Electronic Use	Total
Dominant eye	55	30	103	132	320
Emmetropia	35	6	6	7	54
Hyperopia	15	13	22[a]	25[a]	75
Myopia	0	1	4[a]	7[a]	12
Astigmatism	5	10	71[a,b]	93[a,b]	179
Non-dominant eye	55	30	103	132	320
Emmetropia	35	6	12	20	73
Hyperopia	12	12	34	39	97
Myopia	0	1	8	11	20
Astigmatism	8	11	49	62	130

control group = children who played video games for less than 30 minutes per day and not every day; video game group = children who played video games for 30 minutes or more every day; low electronic use subgroup = children who used other electronic screens for less than 3 hours per day; high electronic use subgroup = children who used other electronic screens for 3 hours or more per day

[a]$P < .001$ for the prevalence of an ametropic state in the dominant eye versus the non-dominant eye in the video game group.

[b]$P < .001$ for the prevalence of astigmatism in the dominant eye versus the non-dominant eye in the video game group.

diatricians (including magnetic resonance imaging scans) to more continuous and persistent forms of headaches that led to a decrease in the child's liveliness and a character change. In fact, some young patients gave the impression of being indifferent, without energy, and almost apathetic, whereas a state of over-excitement and restlessness similar to attention-deficit or hyperactivity syndromes was observed in others. These children frequently suffered from insomnia, especially when they played video games to "relax" before going to sleep. In the video game group, the anamnesis might have been confusing and made it difficult to link the headache to visual fatigue because headaches may appear when no visual effort is being made or even during sleep. Other authors have argued that children often show greater adaptability than adults, such as when regarding viewing comforts. Hence, their high concentration on the game renders them less sensitive to uncomfortable glare, erroneous positioning of the device, and associated bodily symptoms than during less-focused activities such as school or homework.[12]

Second, 5.3% of children presented nervous tics. Because video game performance involves both the visual occipital and motor frontal cortex in a remarkably high-speed and repetitive way, these tics might be assumed to be direct consequences of a high level of brain stimulation. For example, the impulses to the brain increase rapidly in many games depending on the performance of the player and the level of the game, thereby leading to an elevated visual strain, particularly on the dominant eye, and resulting in a loss of fusion. This high level of brain stimulation could lead to a temporary loss of the orthotropic status and transient diplopia in young video game players, although frequent blinking would reset the system to orthotropia and single vision.[30]

Third, on the Lang-Stereotest I, a highly prevalent loss of stereopsis in the video game group was observed, whereas exposure to electronic screens other than video games had no influence on stereopsis in both groups. Common visual tasks at video display terminals (eg, writing or internet surfing) typically provoke saccadic movements of both eyes, whereas video games, which require a quick response to speedy images, might elicit mainly the faster monocular pathways, primarily limited to the dominant eye. Under high-speed gaming conditions, binocular vision would be unnecessary or even counterproductive and would slow the total visual performance. According to several studies, the visual system of children is still at the developing, critical stage, and structural changes have been observed according to the required performance and/or environmental stimuli.[31] Therefore, the brain of a video game player might adapt to the required task by increasing the representation of the dominant eye at the expense of the non-dominant eye. However, these players most likely have healthy binocular cells in areas 17 and 18 of the brain, which are not stimulated due to the monocular pathways that are served first.

The greater brain representation of the preferred eye combined with the suppression of impulses from the non-dominant eye[10,32] might determine an imbalance between the ocular dominance columns of the two eyes in area 17 of the occipital lobe, leading to loss of fine stereopsis.[33] The statistically significant differences between the responses of Lang-Stereotests I and II in the video game group (highly significant absence of stereopsis on the Lang-Stereotest I and positive response to the Lang-Stereotest II) might be explained by the fact that, in contrast to the Lang-Stereotest II, the Lang-Stereotest I has no monocular reference. The presence of one monocularly visible target (star) most likely facilitates binocular vision,[34] also leading to higher recruitment of ocular dominance columns in areas 18 and 19 of the striated occipital cortex.

Similar to the video game group in this study, Ancona et al.[35] found random-dot stereopsis on the Lang-Stereotest II in several cases with small-angle strabismus without motor fusion and large regional suppression, but not on the Lang-Stereotest I. These forms of small-angle strabismus form a diagnostic entity that is different from microtropia as described by Lang.[29] The latter is due to a hereditary predisposition of the alteration of binocular cells in areas 17 and 18, resulting in total lack of random-dot stereopsis with 100% specificity on the Lang-Stereotests.[36] However, if the finding of differing results between the two Lang-Stereotests in the same patient, as encountered in both the current study and the study by Ancona et al.,[35] may be interpreted as a consequence of functional suppression of stimuli from the non-dominant eye at the brain level, these cases could be diagnosed as "functional" microtropia. In contrast to microtropia by Lang,[29] in which the visual system has reached an equilibrium, the functional forms might experience a loss of fusion associated with transient diplopia and, subsequently, acute strabismus.[37,38] It is interesting to note that even a small monocular stimulus separate from the perfectly hidden figures of a random-dot stereotest facilitates stereopsis in a similar way to contour stereotests.[34,39]

The easy-to-perform Lang-Stereotests, which are indispensable for the diagnosis of microtropia[40] and in screening for binocular disorders,[41-44] made it possible to discover this important feature. Furthermore, the comparison of the differing results between the two versions of the Lang-Stereotest could be useful for the study of stereopsis in stressing conditions (eg, video game playing), help with the diagnosis of the proposed syndrome, and eventually give us more information about the cerebral mechanisms of stereopsis.

Fourth, visual defects were more frequent in the dominant eye of patients in the video game group. During examination in relaxed accommodation, reduced visual acuity in the dominant eye was found that could not be improved by correction.[45] Additionally, the refractive errors found were more pronounced in the dominant eye. The higher the speed needed for playing video games, the greater was the effort required from the dominant eye to achieve the best performance in the shortest amount of time possible. Interestingly, reduced visual acuity often improved in cycloplegia, regardless of the nature of the visual defect.

The question of whether these findings reflect an effect on the accommodative system due to the increased effort made by the dominant eye through video game play remains unanswered, but it seems conceivable that the effects of the different strains made by the two eyes might result first in the dominant eye. This could explain the finding that the video game group had a high prevalence of refractive errors, particularly in the dominant eye. Previous studies indicated that the larger brain representation of the preferred eye[10,32,46] would be even more relevant in situations in which the dominant eye performs a demanding visual task. Indeed, studies performed on adult patients with amblyopia have shown significant functional improvements if the preferred eye was covered and the amblyopic eye was trained by playing a video game for a short period of time. The positive results of this treatment might be explained by an increase of impulses to the brain from the amblyopic eye, leading to a partial reduction of the imbalance between the representation on the ocular dominance columns of the two eyes, despite the eventual and partial loss of brain plasticity in these adult patients.[8]

Fifth, a surprisingly large number of patients with an astigmatic defect in the dominant eye was found. This might be explained by the increased mechanical compression exerted by the contracted eyelid muscles during the child's concentration effort on his or her plastic cornea.

Sixth, positive lens prescription for the correction of even minimal values of hyperopia was frequently required. Hence, underdiagnosing of the condition might also result in dependence on spectacles in young children.

For obvious reasons of methodology, these observations could not be answered by the structure of the study. For example, no baseline data prior to the use of video games were obtained and the direct comparison of the low and high electronic use subgroups, which included electronic screens with different properties such as the size of images, movements, contrast glare, and the distance from eye viewing, could be confusing. Furthermore, data considering estimated playing time and parent-reported symptoms could have been biased by the perceptions of parents. Therefore, prospective studies will be needed, possibly in probands who were not yet exposed to video games and with increased exposure times according to a dose–effect paradigm. Even if the data and methodology of the study may be regarded as preliminary, the work describes some interesting findings and hypotheses that merit further in-depth research, including data from age-adjusted cohorts of children not exposed to video games. The results indicate that, although video games seem to improve the visual performance of adults,[7,8] the constant use of video games in children may have an adverse effect on their visual system, which is more subject to modification by the stimuli received due to its neuroplasticity.[10,11] Among all screen-type activities, video games are the source of stimuli that may cause the greatest and shortest-term alterations because they involve all brain functions rapidly and repetitively.

This study had two aims: to draw the attention of pediatric ophthalmologists to the clinical features accompanying frequent video game use in children and subsequently prevent erroneous diagnostic and therapeutic maneuvers, and to stimulate further research. Recognizing these symptoms can improve the clinical approach, provide relief for the young patient's visual system, avoid unnecessary worries for parents, and circumvent the loss of time and money for inappropriate diagnostic tests in the assessment of headaches and general symptoms. More in-depth studies of these alterations are needed to improve understanding of the complexity of the visual system.

REFERENCES

1. Bergqvist UO, Knave BG. Eye discomfort and work with visual display terminals. *Scand J Work Environ Health.* 1994;20:27-33.
2. Cole BL, Maddocks JD, Sharpe K. Effects of VDUs on the eyes: report of a 6-year epidemiological study. *Optom Vis Sci.* 1996;73:512-528.
3. Rechichi C, Scullica L. VDU work: longitudinal survey on refractive defects. *Acta Ophthalmol Scand.* 1996;74:629-631.
4. American Optometric Association. *Guide to the Clinical Aspects of Computer Vision Syndrome.* St. Louis: American Optometric Association; 1995:1.
5. Rechichi C, De Mojà CA, Scullica L. Psychology of computer use: XXXVI. Visual discomfort and different types of work at videodisplay terminals. *Percept Mot Skills.* 1996;82:935-938.
6. Sheedy JE, Hayes JN, Engle J. Is all asthenopia the same? *Optom Vis Sci.* 2003;80:732-739.
7. Green CS, Bavelier D. Action-video-game experience alters the spatial resolution of vision. *Psychol Sci.* 2007;18:88-94.
8. Li RW, Ngo C, Nguyen J, Levi DM. Video-game play induces plasticity in the visual system of adult with amblyopia. *PLoS Biol.* 2011;9:e1001135.
9. Hastings EC, Karas TL, Winsler A, Way E, Madigan A, Tyler S. Young children's video/computer game use: relations with school performance and behavior. *Issues Ment Health Nurs.* 2009;30:638-649.
10. Wallace W, Bear MF. A morphological correlate of synaptic scaling in visual cortex. *J Neurosci.* 2004;24:6928-6938.
11. Maya-Vetencourt JF, Origlia N. Visual cortex plasticity: a complex interplay of genetic and environmental influences. *Neural Plast.* 2012;2012:631965.
12. Kozeis N. Impact of computer use on children's vision. *Hippokratia.* 2009;13:230-231.
13. Blehm C, Vishnu S, Khattak A, Mitra S. Yee RW. Computer vision syndrome: a review. *Surv Ophthalmol.* 2005;50:253-262.
14. Yan Z, Hu L, Chen H, Lu F. Computer vision syndrome: a widely spreading but largely unknown epidemic among computer users. *Computers in Human Behavior.* 2008;24:2026-2042.
15. Fenga C, Aragona P, Cacciola A, et al. Meibomian gland dysfunction and ocular discomfort in video display terminal workers. *Eye (Lond).* 2008;22:91-95.
16. Rosenfield M. Computer vision syndrome: a review of ocular causes and potential treatments. *Ophthalmic Physiol Opt.* 2011;31:502-515.
17. Fenga C, Aragona P, Di Nola C, Spinella R. Comparison of ocular surface disease index and tear osmolarity as markers of ocular surface dysfunction in video terminal display workers. *Am J Ophthalmol.* 2014;158:41-48.
18. Heiting GH, Wan LK. Children and computer vision syndrome. All About Vision Web site. http://www.allaboutvision.com/cvs/children-computer-vision-syndrome.htm. Published 2010.
19. Bedinghaus T. Playing video games may cause eyestrain: encourage safe game play guidelines for your child. VeryWell Web site. https://www.verywell.com/playing-video-games-may-cause-eyestrain-3421596. Updated: February 23, 2017.
20. Vandewater EA, Shim MS, Caplovitz AG. Linking obesity and activity level with children's television and video game use. *J Adolesc.* 2004;27:71-85.
21. Xu S, Xue Y. Pediatric obesity: causes, symptoms, prevention and treatment. *Exp Ther Med.* 2016;11:15-20.
22. Griffiths MD, Hunt N. Dependence on computer games by ado-

lescents. *Psychol Rep*. 1998;82:475-480.
23. Yoo HJ, Cho SC, Ha J, et al. Attention deficit hyperactivity symptoms and internet addiction. *Psychiatry Clin Neurosci*. 2004;58:487-494.
24. Rapporto Nazionale sulla Condizione dell'Infanzia e dell'Adolescenza [National Report on the Condition of Childhood and Adolescence]. Eurispes Web site. http://www.eurispes.eu/content/rapporto-nazionale-sulla-condizione-dell%E2%80%99infanzia-e-dell%E2%80%99adolescenza. Published: 2009.
25. Cheng CY, Yen MY, Lin HY, Hsia WW, Hsu WM. Association of ocular dominance and anisometropic myopia. *Invest Ophthalmol Vis Sci*. 2004;45:2856-2860.
26. Wright KW, Strube YNJ, eds. *Pediatric Ophthalmology and Strabismus*, 3rd ed. New York: Oxford University Press; 2012:217-264.
27. Lang J. A new stereotest. *J Pediatr Ophthalmol Strabismus*. 1983;20:72-74.
28. Julesz B. Stereoscopic vision. *Vision Res*. 1986;26:1601-1612.
29. Lang J. Mikrostrabismus [article in German]. *Monographie, Bücherei des Augenarztes*. 1973;62:1.
30. Maus GW, Duyck M, Lisi M, Collins T, Whitney D, Cavanagh P. Target displacements during eye blinks trigger automatic recalibration of gaze direction. *Curr Biol*. 2017;27:445-450.
31. Baroncelli L, Sale A, Viegi A, et al. Experience-dependent reactivation of ocular dominance plasticity in the adult visual cortex. *Exp Neurol*. 2010;226:100-109.
32. Hubel DH, Wiesel TN. Laminar and columnar distribution of geniculo-cortical fibers in the macaque monkey. *J Comp Neurol*. 1972;146:421-450.
33. Lang J, Rechichi C. Hypothesis on the mechanism of abnormal retinal correspondence: note III [article in Italian]. *Bollettino d'oculistica*. 1990;69:381-386.
34. Lang J, Rechichi C. Considerations on some stereotests: note II [article in Italian]. *Bollettino d'oculistica*. 1990;69:373-379.
35. Ancona C, Stoppani M, Odazio V, La Spina C, Corradetti G, Bandello F. Stereo tests as a screening tool for strabismus: which is the best choice? *Clin Ophthalmol*. 2014;8:2221-2227.
36. Lang J, Rechichi C. Stereopsies in different types of strabismus: note I [article in Italian]. *Bollettino d'oculistica*. 1990;69:365-372.
37. Nucci P. Pediatric ophthalmology and strabismus in Italy. *J AAPOS*. 2004;8:220-221.
38. Kuzhda I, Pityk O. The case of acute strabismus (esotropia) and diplopia, provoked by severe neurogenic accommodative spasm in a child. Poster presented at: 36th European Strabismological Association (ESA) Meeting; September 2013; Marseille, France.
39. Fricke TR, Siderov J. Stereopsis, stereotests, and their relation to vision screening and clinical practice. *Clinical and Experimental Optometry*. 1997;80:165-172.
40. Pai AS, Rose KA, Samarawickrama C, et al. Testability of refraction, stereopsis, and other ocular measures in preschool children: the Sydney Paediatric Eye Disease Study. *J AAPOS*. 2012;16:185-192.
41. Ohlsson J, Villarreal G, Sjöström A, Abrahamsson M, Sjöstrand J. Screening for amblyopia and strabismus with the Lang II stereo card. *Acta Ophthalmol Scand*. 2002;80:163-166.
42. Von Noorden GK, Campos EC. Binocular vision and space perception: stereopsis. In: Von Noorden GK, Campos EC, eds. *Binocular Vision and Ocular Motility: Theory and Management of Strabismus*, 6th ed. St. Louis: Mosby; 2002:21-25.
43. Huynh SC, Ojaimi E, Robaei D, Rose K, Mitchell P. Accuracy of the Lang II stereotests in screening for binocular disorders in 6-year-old children. *Am J Ophthalmol*. 2005;140:1130-1132.
44. Afsari S, Rose KA, Pai AS, et al. Diagnostic reliability and normative values of stereoacuity tests in preschool-aged children. *Br J Ophthalmol*. 2013;97:308-313.
45. Varma R, Tarczy-Hornoch K, Jiang X. Visual impairment in preschool children in the United States: demographic and geographic variations from 2015 to 2060. *JAMA Ophthalmol*. 2017;135:610-616.
46. Hubel DH, Wiesel TN. Stereoscopic vision in macaque monkey: cells sensitive to binocular depth in area 18 of the macaeye monkey cortex. *Nature*. 1970;225:41-42.