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Domitest-S: A Novel Dichoptic Technique to Assess Ocular Sensory Dominance in Children: A Population Study

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Authors' contributions

Author CA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors LC and GP managed the administration of the exam; author TU managed the analyses of the study. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To assess sensory ocular dominance of children by means of a novel psychophysical technique (Domitest-S).
Study Design: population study.
Place and Duration of Study: Department of Ophthalmology, The Gradenigo Hospital, Turin, between June 2012 and June 2013.
Methodology: Thirty sequences of stimuli (15 for the left eye and 15 for the right eye) were administered in dichoptic conditions to 152 pupils (mean age: *9 ± .8* years). The task was to detect the target (a checkerboard-like pattern arranged so as to form an "X") embedded in a series of null stimuli (checkerboard-like patterns randomly arranged). Left and right proportion correct responses were computed and an index of dominance laterality, the *Balance Value (BV),* expressed as the right minus left proportion correct responses was introduced. A second index based on the total amount of percent correct responses, the *Interocular Inhibitory Index (III)* was computed to provide a measure of reciprocal binocular suppression.
Results: The frequency distribution of sensory dominance was not normal, but skewed on the left (*KS=.17, P<.001*). The median was .20 (range *.00-.80*) with 77% of the subjects showing a BV between .00 and .27. A substantial equivalence was found

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between the proportion of right and left dominants (46%). Balance values ranging from –.20 to +.27 accounted for 79% of the variance. The distribution of the reciprocal interocular suppression measured as *III* was bimodal, showing two peaks, one on the right (lower inter-inhibitory effect) and the other on the left (stronger inter-inhibitory effect). Test-retest reliability was acceptable (correlation between the left and right correct responses at first and second examination: Spearman *r= .54*, *P< .001*). The duration of the examination was about 5 minutes.
Conclusion: Domitest-S proves to be a fast and reliable technique to assess sensory dominance in children within the clinical setting.

Keywords: Ocular dominance; domitest-S; interocular inhibition; dichoptic; RSVP.

1. INTRODUCTION

The assessment of ocular dominance is a topic of great interest in ophthalmological field, as it is the basis for optical and clinical remediation [1,2]. In addition, ocular dominance may be involved in a number of neuropsychological conditions like developmental dyslexia [3-6] and spatial neglect [7]. In the first case, weak dominance is found to reduce fixation stability when reading, in the second case eye dominance laterality would influence the direction of visuoattentional bias. Finally, ocular dominance is found to affect head posture and mandibular position in children [8,9], since variation in eye dominance would be related to transverse head postural changes and mandibular deviations. For these reasons, there is evidence that eye dominance may affect the outcome of the rehabilitation in subjects suffering from a variety of visual, neuropsychiatric, postural and gnathologic disorders.

The term “ocular dominance” is comprehensive of both the motor and sensory aspect, since it can refer to the preferred visual axis (“sighting dominance”) or to the input taken as the reference when looking binocularly, respectively. In fact, motor and sensory ocular dominance rely on different functional bases and should therefore be considered separately. The assessment of motor (or sighting) dominance makes use of tests aimed at detecting the preferred visual axis when performing a monocular task. In this respect, probably the most common technique employed in the clinical practice is the so-called hole-in-the-card test [10].

On the contrary, there is no common agreement on the gold standard for the estimate of sensory dominance that is to say for establishing which is the eye whose image processing is salient compared to the contra lateral one. Indeed, a number of psychophysical tests have been devised for this purpose. The assessment is based on the left/right difference in sensitivity for different visual functions or in visual acuity, and especially on dichoptic or binocular rivalry-based paradigms [11-17]. Exams making use of dichoptic presentations aim at identifying which of the two eyes is less susceptible to suppression. These techniques are of particular interest, since besides detecting the dominant eye they provide objective measurement of the strength of the sensory dominance. In fact, by simultaneously presenting a different stimulus to each eye, the degree of left/right sensory dominance can be estimated psychophysically.

Ooi et al. [16] for example devised a method to assess the sensory balance point between the two eyes by presenting gratings differing in colour and orientation in dichoptic conditions. Handa adopted a similar technique and used contrast as a variable instead of colour in normal subjects [14,15] and in patients affected by cataract [15].

Mapp measured the duration of exclusive visibility of each eye as a function of the contrast of rectangular gratings in a binocular rivalry paradigm [11].

Yang [13] made use of the continuous flash suppression display [18] to measure in dichoptic stimulation the suppression threshold of a Mondrian pattern presented to one eye on a target displayed to the contra lateral eye.

Li measured sensory eye dominance by means of a dichoptic motion coherence task [12]. In this experiment, one eye was presented a field of random dots while the other was displayed a field of coherently moving dots. Subjects were asked to indicate the coherent motion direction, and the strength of dominance was evaluated by changing the proportion of coherent dots presented to the right and left eye according to a staircase algorithm.

Evidently these models, which have been tested in adult subjects, look to be quite demanding and are probably too time consuming, so their usefulness in clinical practice (and especially in children) is arguable.

Recently, Valle-Inclán et al. [17] reported a rapid serial visual presentation-based strategy, which looks to be more suitable for the clinical setting. In the rapid serial visual presentation (RSVP, [19]), a sequence of letters is displayed tachiostoscopically in the same position. Within the sequence, one letter is the target to be detected or identified. By presenting two streams of letters in dichoptic conditions, the authors plotted the cumulative function of left/right dominance in a sample of adult normal subjects.

In this paper a novel RSVP-based dichoptic technique intentionally devised for testing children is described. Even if the test is derived from the aforementioned model, it differs in some substantial aspects. The results collected in a sample of more than 150 normal readers in the 3rd, 4th and 5th school grade are reported.

2. MATERIAL AND METHODS

Fifteen pairs of sequences, each made of 10 stimuli subtending a visual angle of 1° in foveal projection and at a viewing distance of 70 cm, were displayed dichophtically on a 262K LCD colour monitor (1280 x 800 pixels, 10.1 inch, 60 Hz) according to a rapid serial visual presentation paradigm (RSVP). The head of the observer was constrained on a chinrest. The left and right sequences were presented simultaneously and binocular vision of each stream was prevented through a rectangular cardboard mask (50.5 cm wide x 25 cm high) placed perpendicularly between the midline of the screen and the face of the patient and aligned to the nose.

The task was to detect a target (5x5 matrix made of 0.2° wide black and white squares arranged to form an “X”) embedded in a sequence of null stimuli (matrices of black and white squares arranged in pseudorandom order to form a checkerboard-like pattern). The luminance of the black and white squares was .3 and 240 cd/m^2, respectively; background luminance was 240 cd/m^2. Luminance of the environment was about 80 cd/m^2. The stimuli were projected 2 deg apart from the midline for 200 msec, with no interstimulus interval: thereby, the duration of each sequence was 2 sec. At every trial, the target was presented to either the left or the right eye in a random manner and in random position, from position 3 to position 9. The subject was asked to report the detection of the target after each trial, and, if this was the case, on which side (left or right stream: Fig. 1). The technician, in turn, would record the response by pressing the left or right button on a remote control. The child was allowed to respond from the moment he/she perceived the target during the presentation of the sequence until 2 seconds after the disappearance of the last stimulus, according to a yes/no paradigm. In the presence of the target, no response was considered as a miss answer and the next trial would occur after 2 seconds, whereas in false positive trials (no target presented) it reveals reliable performance.

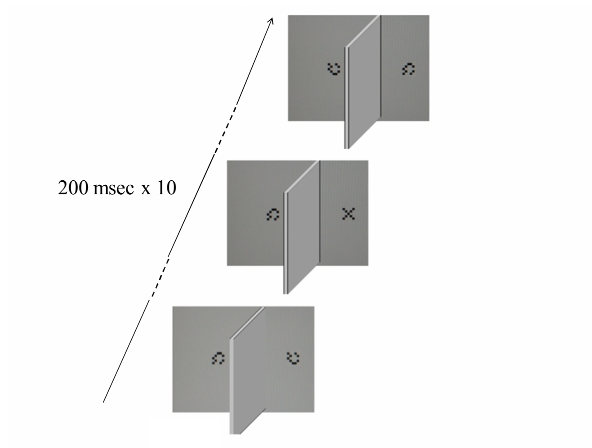

Fig. 1. The last three presentations of a stream of stimuli in the dichoptic RSVP technique used in the experiment. Each stimulus is displayed to one eye. In this trial, the target is presented to the right eye at position 9.

In order to provide an estimate of test reliability, in fact, false positive (FP) and false negative (FN) errors have been computed by administering respectively 3 sequences with no target and 3 trials with the two targets displayed in the same temporal position within the stream (i.e. simultaneously to both eyes).

The exam was preceded by a brief training session made of 2 sequences each lasting 5 seconds. The children were instructed to respond only when they were sure to have perceived the cross, and that it could happen that target was not presented. In order to make more friendly the task, the functioning of the test was explained as if it was a videogame: "tell us if you see the crossroads." Before presenting the trials, the technician made sure that the child had fully understood the task.

At the end of the test, the Balance Value (BV) was computed as the difference between the right-left proportions of correct responses and taken as an indicator of sensory eye dominance. A positive BV means right dominance; negative value means left dominance, the higher the ratio, the more lateralized is the sensory dominance. BV=0 means no dominance.

One hundred and fifty two children, mean age 9.0 ± 0.8 years, recruited from a primary school participated the study. After obtaining written informed consent from their parents, all subjects underwent a preliminary ophthalmological and orthoptic examination. Their best corrected visual acuity in both eyes was higher than 20/25. Exclusion criteria were ophthalmological diseases, manifest strabismus, absent or poor stereopsis, refractive errors > ±1D, systemic or neuropsychiatric diseases and poor collaboration.

All authors hereby declare that the experiment has been examined and approved by the Gradenigo Hospital ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 declaration of Helsinki.

3. RESULTS

In the scholar sample the proportion of right and left dominants was substantially the same, being respectively 45.75% and 45.1%. The remaining 9.15% of subjects did not show dominance laterality (BV=0).

The BV in the population tended to be normally distributed (KS=.065, *P*=.070), in line with the previous results obtained with binocular rivalry-based techniques aimed at assessing sensory dominance [9,10], with 73% of the subjects showing a BV between -0.2 and +0.27. However, when considering BV as an absolute value, the distribution departed from normality (KS=.17, *P*< .001). In this case the median was 0.20 (range 0.00-0.80), with 77% of the subjects showing a BV between 0 and 0.27.

Twenty-nine per cent of the subjects made at least 1 false positive error. In order to obtain a highly reliable sample, these cases have been excluded. Like in the overall sample, also in the reliable sample the proportion of the right and left dominants was roughly the same (45.37% vs 46.2%), with 8.33% of subjects who did not show dominance laterality. In agreement with the overall sample, 79% of the subjects showed a BV between -0.2 and +0.27. However, compared to the overall sample, the BV distribution departed from the normality (KS=.09, *P*=.010) and turned out to be bimodal with a peak at -0.13 and 0.2 (Fig. 2). After treating BVs as absolute values, the distribution was skewed on the left (KS= .16, *P*<.001). In this case, the median was 0.20 (range 0-0.67), with 79% of the subjects showing a BV between 0 and 0.27. These findings are resumed in Fig. 2.

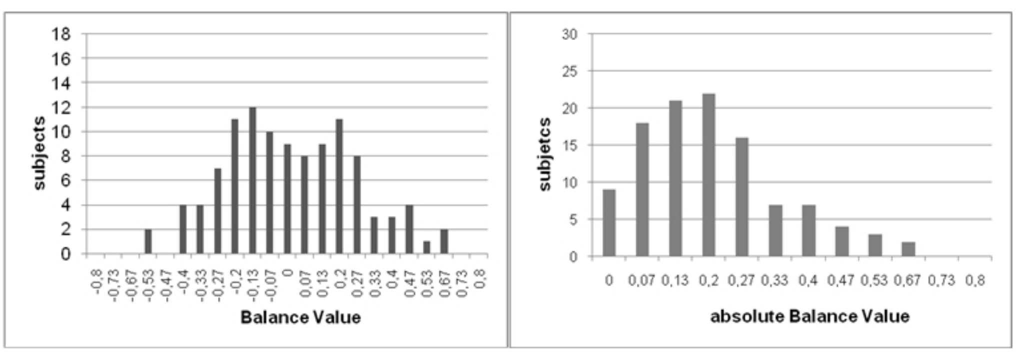

Fig. 2. Left: Frequency distribution of BV in the reliable sample. Right: absolute values. In the left panel: left eye dominant: negative values, right eye dominant: positive values.

In the sample, overall right and left percent correct responses were 0.48 (±0.23) and 0.46 (±0.22), respectively (median: 0.47 in both cases). The difference was not significant (*P*= .57, Wilcox on matched paired test).

In figure 3, left panel, the sum of left+right proportion correct responses is plotted as a function of BV in the reliable sample. Value distribution turned out to be uniform (correlation between proportion correct responses and BV not significant: Spearman *r* =.07, *P*= .93): therefore, the proportion correct score is not related to the BV and, as a matter of fact, the same BV can be obtained with different hit rates.

Like the BV, also the distribution of the percent correct responses in the population is not normal (KS= .10, P= .006), but shows a bimodal pattern, peaking at 0.67, and at 1.27 (Fig. 3, right panel).

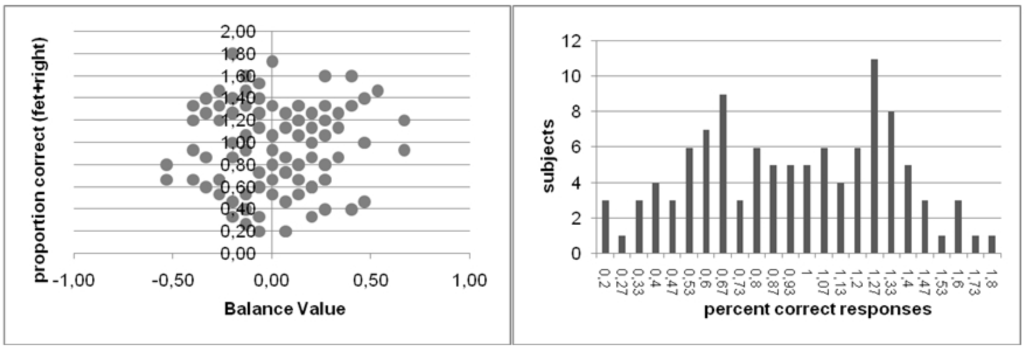

Fig. 3. Left: proportion correct responses as a function of BV in the reliable sample. Right: distribution of the percent correct responses

To assess test-retest reliability, after some weeks a group of 19 children with the same characteristics of the recruited scholar population were tested twice during the same day (time interval: 20 minutes). The correlation between the proportion of left and right correct responses in the first and second examination was significant (Spearman *r*= .54, *P*< .001). The average proportion of correct responses was slightly higher in the second examination (0.74 ± 0.18 vs 0.76 ± 0.16), probably due to a learning effect. However the difference was not statistically significant (*P*=.70).

The second examination confirmed the laterality of dominance (left/right) in 11 of 19 subjects. The eight cases that showed laterality incongruence were those with the lowest BVs (<0.13). Indeed, subjects with the lowest BVs are those whose dominance is weaker, that is to say less stable, as opposite with the majority of children who showed BV higher than 0.13 (with a peak at 0.2) in the surveyed population. It is therefore predictable that unstable dominants tend to switch their preferred eye when performing the task in different sessions, making the outcome after subsequent examinations variable.

3. DISCUSSION

Even if the assessment of ocular dominance is a topic of great interest in clinical practice (since it can drive therapeutic decisions), it is still a controversial subject. The lack of distinction between motor and sensory dominance may contribute to explain many conflicting results. It is claimed that sighting (motor) dominance simply refers to the preferred eye used when required to view monocular [11], whereas sensory dominance is expected to reflect the true binocular inhibitory pattern.

Binocular rivalry and the dichoptic presentation in general is perhaps the most promising approach to assess sensory dominance. Even if a number of studies have been addressed to evaluate its usefulness in adult subjects [11-17], as far as we know these techniques have not been estimated in children. Chia et al measured sighting dominance but not sensory dominance in more than 500 children [20]. Recently, a chart for the clinical setting of sensory dominance was proposed by Handa et al. [21]. The test, which makes use of a balancing technique in a binocular rivalry paradigm, has been evaluated in a sample of young patients (age 18-25), albeit not children.

Yet, sensory ocular dominance may be a crucial factor in children suffering (or suspected to suffer) from a number of neuropsychological conditions. In dyslexic pupils, for example, this function may have an important role since unstable dominance is believed to lead to fixation instability, and fixation instability in turn would account for many of the symptoms and signs in a subgroup of patients, therefore defined as “visual dyslexics” [3-6].

Since the techniques advanced so far do not seem suitable in children, being too demanding under a cognitive point of view and probably too time-consuming, a fast, simple and reliable test to assess sensory dominance is desirable in the perspective of its use in the clinical practice.

It has been argued that the estimate of sensory dominance based on binocular rivalry tends to be biased [17]: since binocular rivalry occurs when the alternation of the images is slow, RSVP, being free from this drawback, would therefore be preferable.

The Domitest-S is a RSVP-based dichotic paradigm aimed at estimating by means of a simple task the sensory dominance in clinical practice, and especially in children. It is similar to the method recently presented by Valle-Inclán et al. [17] and tested in adult subjects. The main difference is that in our case the task is to detect a checkerboard-like matrix arranged to form an “X” embedded in a stream of randomly arranged checkerboard-like patterns, instead of a character among characters or a digit among characters. In addition, the number of the trials is lower and the background and average stimuli luminance are higher (photopic condition). Finally, we used a grey rectangular cardboard instead of a mirror stereoscope to ensure the dichoptic presentation.

Like the test devised by the Spanish group, in our tachistoscopic technique binocular rivalry is avoided. Moreover, irrespective of the presentation time, in our paradigm one of the two sequences of stimuli is made of null configurations: we believe that this absence of informational content makes the occurrence of ocular rivalry even less probable.

In agreement with the results obtained in young adults by Valle-Inclán et al, in children, too, the proportion of left- and right-eye dominance is the same; still, in our investigation about 8% of the reliable subjects did not show any laterality preference.

In a previous study the frequency distribution of the sensory dominance is found not to be normal, showing two different subpopulations: weak and strong dominants [5]. In the present experiment, too, the distribution of the dominance laterality as expressed by the BV turned out to be non parametric, showing asymmetric tails with a peak of lateralization at 0.2 and 71% of children with sensory dominance imbalance ranging from 0.07 to 0.27 (irrespective of the left/right sense of lateralization).

Interestingly, in our cases the same BV can be observed with different proportion correct responses. Since a higher or lower proportion of correct responses can be obtained irrespective of the BV, we believe such a discrepancy may reflect differences in the interocular suppression.

As a matter of fact, when performing binocular (non dichoptic) single RSVPs, adult subjects are found to be able to detect a simple target with a probability of .80- .85 [19]. We have found the detection rate of the two RSVPs in our dichoptic conditions is lower by about 50%. The reason for this difference could depend on the inhibitory interaction between the sensory output from the two eyes, more evident when stimuli are presented dichoptically: indeed, a consistent body of evidence shows that inhibitory inputs affect the binocular combination of the stimuli [22-26], suggesting inhibitory binocular imbalance to be the basis for sensory ocular dominance. In this perspective, recently Said and Heeger improved the conventional models for binocular rivalry by adding to the binocular summation neurons a pool of opponent neurons to the binocular inhibitory pathway [27].

In this perspective, for a given BV, a lower left+right percent correct score when performing the RSVP dichoptically may be due to a cumulative stronger interocular inhibitory effect during the two sequence presentations. On the contrary, a higher hit rate could be due to a lower interocular inhibitory effect.

To make more intuitive the estimate of this interocular inhibitory effect, we have turned the percent correct scores into an index, the Interocular Inhibitory Index (III):

$$III = 2-(L_{\text{percent correct}} + R_{\text{percent correct}}).$$

In the temporal domain, we suggest this measure expresses the cumulative duration of the interocular inhibition during the presentation of the sequence (“silent intervals”): the longer the cumulative period of this reciprocal binocular suppression (RBS), the lower the proportion correct responses, the higher the III. Virtually, if the RBS lasted the whole interval of the sequence (200 msec), interocular inhibition would affect reciprocally the two eyes for as long as the duration of the stream: since the percent correct score both on the left and on the right would approach 0, the value of III would be at its maximum (2.0). On the contrary, if the RBS were absent, the percent correct score would be 100% on the left and 100% on the right (i.e. 200%), so that according to the equation, the III would approximate 0. Within these two extremes, a spectrum of intermediate degrees of interocular inhibition can be hypothesized. The distribution of the reciprocal inhibition in the recruited population as estimated by means of the III was bimodal, showing two intermediate peaks, one, lower, on the right (stronger inter-inhibitory effect) and the other, higher, on the left (weaker inter-inhibitory effect) (Fig. 4).

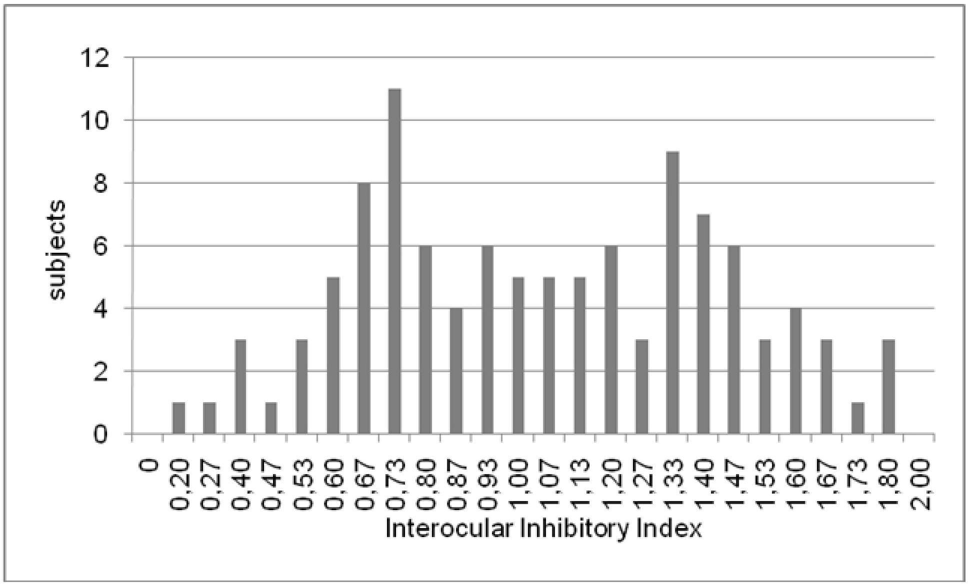

Fig. 4. The frequency distribution of the III in the recruited scholar population. It can be noted that the index depends on overall percent correct responses (compare with figure 3, right panel)

In summary, we suggest the III refers to the total amount of reciprocal inhibition during the sequence whereas the BV would express the degree of dominance lateralization during the spared phases of no-simultaneous reciprocal inhibition.

False positive responses were less than 12% of the total false positive presentations, a proportion in agreement with a previous RSVP study in binocular and not dichotic conditions (mean false alarm rate: 12.6-11.3% [19]). This means that in absence of the target in the two sequences (as well as when a single stream of stimuli is presented) subjects are not quite prone to answer by chance. On the contrary, the rate of false negative errors was far higher, rising up to 64% of the total false negative presentations. This suggests that when two targets are displayed in the same temporal position across the two sequences, subjects tend to ignore them. As a hypothetical explanation, during the simultaneous presentation of the two targets, the RBS would prevent the two stimuli from being detected. When it is required to report the detection of the target on the left or on the right stream, a simultaneous presentation could make the subject confused, leading to a missed answer, and get graded as if he/she did not see either. Yet, such a possible methodological bias should also involve (and even more) the false positive trials, where only randomly arranged checkerboard patterns are displayed, so that the observer can get confused, mix up a null stimulus with the target and eventually report a “ghost” stimulus. And yet, as reported, false positive rate is far lower, in line with previous studies (less than 12%). The high proportion of false negative errors does not seem related to a difficulty in performing the test and therefore in solving the false negative trials, as up to 88% of the children whose false positive rate was 0% (therefore whose performance at domitest-S can be considered as optimal), made false negative errors to a certain amount. Finally, the inhibitory effect documented with the false positive assessment had been previously found by Valle-Inclán, et al [2008], who made use of a similar psychophysical paradigm. They reported that *“[…] observers […] were surprised* *to learn after the experiment that two letters were simultaneously presented. This perceptual suppression of one of the monocular streams was constant through the whole trial […]*.

In their case, two clearly recognizable targets were presented (letters or digits), making it probably easier to detect at least one. On the contrary, the checkerboard pattern used in our paradigm might be a more difficult task, so that the perceptual suppression would occur in both streams.

The lack of statistically significant correlation between false negative errors and *III* would exclude the possibility that such a presumed inhibitory effect would simply reflect poor collaboration, attention or scarce motivation.

The reciprocal inhibitory effect of a dichoptic presentation can be regarded under a visuoattentive perspective. Raymond et al. [12] reported the occurrence of attentional "blinks" when subjects perform multiple-task RSVPs: after the first target is detected, in fact, the subsequent detection is delayed by up to 700 msec in the case that the target were words [28], by 300 msec in the case that the target was a digit [29], by 180-270 msec for letters and by 180-450 msec for items similar to the one used in our investigation (a black "X") [19]. We suggest that quite a similar mechanism may explain the differences we have found in the proportion correct responses in dichoptic conditions. The lower occurrence of hit rates in our paradigm would not depend on a suppressive effect of the previous stimulus on the subsequent ones within the same left or right sequence, since in this case the percent correct rate is expected to be far higher than found (i.e. about 0.8, in agreement with the aforementioned previous studies). On the contrary, we suggest the suppressive effect of the target presented to one (for example the right eye: R1) affects to a variable degree the immediate subsequent stimuli presented to the contra lateral one (L2,L3, L4), and vice versa.

In summary, the simple comparison between hit rates on the left and on the right eye is not enough to fully account for the sensory dominance when a dichoptic technique is adopted: it is necessary to consider the amount of the interocular inhibition, as well.

As a matter of fact, dichoptic stimulation is not the optimal paradigm for the estimate of sensory eye dominance, since it does not meet the natural conditions of vision. In fact, binocular fusion is not preserved. It follows that the estimate of the sensory dominance based on such a paradigm can be biased to some extent. Still, the ocular dominance assessment, that is to say the measure of the relative contribution of each eye to single binocular vision, as far as we know is not yet evaluable with techniques preserving the fusion of the stimulus, so that (as testified by a large body of literature) the best solution so far remains dichoptic or binocular rivalry-based paradigms.

In addition, in the present study control of fixation is not provided. Even if the modality of presentation of the technique described in this paper is in line with other similar methods for the estimate of sensory dominance available in literature, accurate foveal fixation is a requisite that cannot be ignored, in order to rule out interemispheric stimulation. This is a point that should be addressed in future research on eye dominance.

4. CONCLUSION

Domitest-S looks to be a fast and reliable technique to measure sensory dominance in children. It provides an estimate of the degree of dominance lateralization as well as (putatively) the total amount of the interocular inhibitory effect. In addition, test reliability estimation is reported at the end of the examination by measuring the false positive rate. This judgment is particularly important when dealing with young patients in the clinical practice. Domitest-S takes about 5 minutes to be performed, does not require letter identification, and is therefore not particularly demanding for children.

For these reason, it seems to be suitable within the clinical setting when the assessment of sensory dominance in children is required, with particular regard to those affected by reading disability.

CONSENT

All authors declare that written informed consent was obtained from the parents of the children for publication of this study.

ETHICAL APPROVAL

All authors hereby declare that all experiment has been examined and approved by the Gradenigo Hospital ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that the Domitest-S makes part of the TETRA^{TM} platform.

REFERENCES

1. Evans BJ. Monovision: a review. Ophthalmic Physiol Opt. 2007;27(5):417-39.
2. Efron N. Contact lens practice. Ed. Woburn, MA: Butterworth- Heinemann; 2003.
3. Stein JF, Fowler S. Diagnosis of dyslexia by means of a new indicator of eye dominance. Brit J Ophthalmol. 1982;66(5):332-36.
4. Stein JF, Fowler S. A physiological theory of visual dyslexia. In: Rose editor. Advances in Neurology. Progress in Aphasiology. Ed. New York: Raven Press; 1984.
5. Stein JF, Riddell PM, Fowler S. Fine binocular control in dyslexic children. Eye. 1987;1(pt3):433-38.
6. Stein JF, Fowler S. Unstable binocular control in children with specific reading retardation. J Read Res. 1993;16(1):30-45.
7. Roth HL, Lora AN, Heilman KM. Effects of monocular viewing and eye dominance on spatial attention. Brain. 2002;125:2023-35.
8. Pradham NS, White GE, Mehta N, Forgione A. Mandibular deviations in TDM and non-TDM groups related to eye dominance and head posture. J Clin Pediatr Dent. 2001;25(2):147-55.
9. Lin SY, White GE. Mandibular position and head posture as a function of eye dominance. J Clin Pediatr Dent. 1996;20(2):133-40.
10. Gould G. A method of determining ocular dominance. JAMA. 1910;55:360-70.
11. Mapp AP, Ono H, Barbeito R. What does the dominant eye dominate? A brief and somewhat contendious review. Percept Psychophys. 2003;65(2):310-17.
12. Li J, Lam CS, Yu M, Hess RF, Chan LY, Maehara G, et al. Quantifying sensory eye dominance in the normal visual system: a new technique and insights into variation across traditional tests. Invest Ophthalmol Vis Sci. 2010;51(12):6875-81.

13. Yang E, Blake R, McDonald JE. A new interocular suppression technique for measuring sensory eye dominance. Invest Ophthalmol Vis Sci. 2010;51(1):588-93.
14. Handa T, Mukuno K, Uozato H, Niida T, Shoji N, Shimizu K. Effects of dominant and nondominant eyes in binocular rivalry. Optom Vis Sci. 2004;81(5):377-83.
15. Handa T, Uozato H, Higa R, Nitta M, Kawamorita T, Ishikawa H et al. Quantitative measurement of ocular dominance using binocular rivalry induced by retinometers. J Cataract Refract Surg. 2006;32(5):831-36.
16. Ooi TL, He ZJ. Sensory eye dominance. Optometry. 2001;72(3):168-78.
17. Valle-Inclán F, Blanco MJ, Soto D, Leiros L. A new method to assess eye dominance. Psicológica. 2008;29:55-64.
18. Tscuchiya N, Koch C. Continuous flash suppression reduces negative afterimages. Nature Neurosci. 2005;8(8):1096-101.
19. Raymond JE, Shapiro KL, Arnell KM. Temporary suppression of visual processing in an RSVP task: An attentional blink? J Exp Psychol Human. 1992;18(3):849-60.
20. Chia A, Jaurique A, Gazzard G, Wang Y, Tan D, Stone RA, *et al*. Ocular dominance, laterality, and refraction in Singaporean children. Invest Ophthalmol Vis Sci. 2007;48(8):3533-36.
21. Handa T, Shimizu K, Uozato H, Shoij N, Ishikawa H. A new method for quantifying ocular dominance using the balancing technique. Am Orthopt J. 2012;62:77-86.
22. Mansouri B, Thompson B, Hess RF. Measurement of suprathresold binocular interactions in amblyopia. Vision Res. 2008;48(28):2775-84.
23. Baker DH, Meese TS, Summers RJ. Psychophysical evidence for two routes to suppression before binocular summation of signals in human vision. Neurosci. 2007;146(1):435-48.
24. Baker DH, Meese TS, Georgeson MA. Binocular interaction: contrast matching and contrast discrimination are predicted by the same model. Spat Vis. 2007;20(5):397-413.
25. Baker DH, Meese TS, Hess RF. Contrast masking in strabismic amblyopia: attenuation, noise, interocular suppression and binocular summation. Vision Res. 2008;48(15):1625-40.
26. Hess RF, Hutchinson CV, Ledgeway T, Mansouri B. Binocular influences on global motion processing in the human visual system. Vision Res. 2007;47(12):1682-92.
27. Said CP, Heeger DJ. A model of binocular rivalry and cross-orientation suppression. PLoS Comput. Biol. 2013;9(3), e1002991. doi:10.1371/journal.pcbi.1002991:1-12.
28. Broadbent DE, Broadbent MHP. From detection to identification: response to multiple targets in rapid serial visual presentation. Percept Psychophys. 1987;42(2):105-13.
29. Weichselgartner E, Sperling G. Dynamics of automatic and controlled visual attention. Science. 1987;238(4828):778-80.

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