International Journal of Physical Medicine & Rehabilitation

Mancuso M, et al., Int J Phys Med Rehabil 2016, 4:4
DOI:10.4172/2329-9096.1000355

Research Article Open Access

Efficacy of Prisms in Neglect Treatment: A Randomized Single Blind Study

Mancuso Mauro[1*], Capitani Donatella[2], Ferroni Lucia[3], Caputo Marina[4], Bartalini Brunella[5] , Abbruzzese Laura[1], Pirrotta Fabio[1], Rossi Giulia[6], Pacini Maura[6], Spaccavento Simona[7], Asnicar Maria[8], Farinello Carla[9], Gemignani Paola[10] and Cantagallo Anna[11]

[1]CRT, Rehabilitation Center Terranuova, Arezzo, Italy

[2]Information Communication Technology, USL, South-East NHS, Grosseto, Tuscany, Italy

[3]Rehabilitation Unit, USL, North-West-Lucca, Tuscany, Italy

[4]Rehabilitation Unit, Auxilium Vitae, Volterra, Italy

[5]Rehabilitation Unit, NHS-ASL12, Viareggio, Italy

[6]Rehabilitation Unit, USL, South-East-Grosseto, Tuscany, Italy

[7]Neurorehabilitation Unit, IRCCS S.Maugeri Fondation, Cassano Murge, Bari, Italy

[8]Rehabilitation Unit, Rovereto, Italy

[9]Rehabilitation Unit, Saint Bortolo Hospital, NHS-ULSS 6, Vicenza, Italy

[10]Neuropsychological and SpeachTherapy Unit, Don Gnocchi Foundation, Sarzana, Italy

[11]BrainCare, Padova, Italy

[*]**Corresponding author:** Mancuso Mauro, Scientific and Clinical Head at the CRT (Rehabilitation Center of Terranuova-AR-Italy), Specialization in Neurology and Physiatry, Tel: + 393338170438; E-mail: m.mancuso62@gmail.com

Received date: June 10, 2016; **Accepted date:** June 20, 2016; **Published date:** July 25, 2016

Abstract

Objective: Unilateral Spatial Neglect (USN) commonly occurs after lesions in the right hemisphere. This complex syndrome can be defined as a failure to report, respond, or orient to contralateral stimuli. Patients show several symptoms in everyday life, such as eating only on the right side of the plate, or forgetting to look left before crossing the street.

Among the different bottom-up treatments, prisms adaptation has found considerable application, producing a high number of scientific papers, even if these are not always consistent in their conclusions.

The aim of this randomized single blind study was to verify the efficacy of prisms in improving neglect syndrome when compared to neutral lenses in a group of stroke in patients with neglect.

Methods: All patients were randomized into two groups: Experimental Group (EG) and Control Group (CG). The EG was treated with pointing exercises wearing prismatic lenses producing a deviation of the visual field of 10° to the right, while the CG was treated with pointing exercises wearing neutral lenses that did not produce any deviation of the visual field. Both groups were treated for two weeks.

We compared with Analysis of Variance the two groups of stroke patients at two different treatment times, at the enrollment time (T0) and after two weeks (T1).

Results: We have compared the EG and CG at T0 and T1 time: both groups show a significant improvement in outcome measure. The analysis between groups highlights that this effect can be related to the time rather than to the group of treatment.

Conclusion: According to our results we can conclude that pointing with no visible arm is useful in neglect treatment and that prisms produce some further benefits even if the low number of subjects enrolled is still insufficient to give clear evidence in the use of prisms.

Keywords: Neglect; Prismatic lenses; Rehabilitation; Stroke; Inattention; Neuropsychology; Outcome

Introduction

The unilateral spatial neglect results from a unilateral hemispheric lesion (most often in the right hemisphere) that involves inferior and superior parietal lobes, some portions of the frontal lobe [1,2] and the white matter that connects these parietal and prefrontal regions [3-5].

Unilateral Spatial Neglect (USN) commonly occurs after lesions in the right hemisphere (90% of cases), particularly in the parietal (inferior), temporal (superior), and/or frontal (ventral) cortex and sometimes in subcortical nuclei [6]. This complex syndrome can be defined as "a failure to report, respond, or orient to contralateral

stimuli that is not caused by an elemental sensorimotor deficit" [7]. Patients with USN may show several symptoms in everyday life, such as eating food only on the right side of the plate, putting make-up only on the right side of their face and, forgetting to look left before crossing the street [8,9].

It is generally agreed that this syndrome is a common consequence of the right hemisphere stroke [10] but it can also be observed in patients with left hemisphere lesions [11-12]. When left hemiplegia is associated with neglect, motor deficit is more severe than in patients without hemi-spatial inattention [13].

The presence of USN affects negatively both motor and cognitive rehabilitation outcomes [14,15].

Anosognosia, when present, significantly worsens the outcome [16,17]. Several researchers have highlighted that neglect predicts poor functional recovery more than aphasia [15,18] and as patients are often impaired in daily living activities (i.e. eating, washing, shaving or dressing left side of their body), they need continuous care with a significant loss of quality of life.

The different rehabilitative treatments can be divided into two different categories: top-down and bottom-up. The application of the former requires a good voluntary control of attentional awareness, while the latter does not need these components as it automatically changes the behavior of the patient [19].

In the last years, among the different bottom-up treatments, prisms adaptation [20] has found considerable application, producing a high number of scientific papers, even if these are not always consistent in their conclusions [21]. This method is easy in administration, and due to the presence of adaptation, it is easy to predict the effectiveness of the treatment from the early sessions [22]. Adaptation is the ability of the patient to adapt to the new visual condition wearing prismatic lenses.

As described by Rossettì in 1998 and experimented in Italy for the first time in 2002 by Frassinetti, prisms method consists in asking the patient to point towards a visual target, with the right upper limb, wearing prismatic lenses of 20 diopters. The treatment with prismatic lensesis normally conducted for 10 daily sessions, lasting about 30 minutes each, distributed over 2 weeks [20,23]. According to literature, the improvement can be due to a reorganization of spatial representation at a higher level mediated by the "recalibration" of the visual-motor coordinates, induced by prismatic lenses [22,23], and the effect seems to be persistent for many weeks [24,25]. A lot of papers show that, whereas there is a significant consensus in evaluating symptoms, there is still little agreement on which are the best methods to treat neglect syndrome. At the moment there are a lot of methods to treat neglect syndrome [26,27] but unfortunately there is poor evidence on the their efficacy. This can be correlated to the different methodologies used in comparing the various approaches and to the fact that most researches fail to correctly document the effects of treatments on daily living activities. The paper and pen neuropsychological tests that neuropsychologists normally used to measure the outcome are less sensitive to highlight the real effect of the rehabilitation treatment on the patients' daily abilities. In fact, papers which consider different outcome measures such as the use of the wheelchair [28] are rare and, moreover, the sample size of treated patients is not sufficient for valid statistic evaluation.

The aim of this randomized single blind study was to verify the efficacy of prisms [23] in improving neglect syndrome when compared to neutral lenses in a group of stroke in patients with neglect.

Methods

All patients were randomized by the coordinating center, into two groups: Experimental Group (EG) and Control Group (CG). The EG was treated with pointing exercises wearing prismatic lenses producing a deviation of the visual field of 10° to the right, while the CG was treated with pointing exercises wearing neutral lenses that did not produce any deviation of the visual field.

The two groups were assessed at baseline (T0) and at the end of treatment (T1) after two weeks. In order to understand if prisms application produce a therapeutic effect in neglect treatment, we compared with Analysis of Variance the two groups of stroke patients at two different treatment times, T0 at the enrollment time and T1 after two weeks of pointing treatment with prisms (EG) or with neutral lenses (CG).

Participants

For our study we enrolled from 9 different Italian rehabilitation centers 52 stroke patients affected by neglect syndrome.

All patients signed informed consent before participating in the study, conducted according to principles of the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the coordinating center.

Inclusion criteria were: brain vascular lesion in the right hemisphere documented with CT scan, diagnosis of neglect resulting from clinical assessment and a span of time of less than 6 months from the onset of brain lesion.

The presence of cognitive impairment (Mini-Mental State Examination score less than 21 points), a prior brain injury, severe impairment of vision or severe hemianopsia, psychiatric disorders and alcohol and/or drugs abuse led to exclusion from the study.

Procedure

All patients who met the inclusion criteria were randomized by the coordinating center, into two groups: Experimental Group (EG) treated with pointing exercises, wearing prismatic lenses producing a deviation of the visual field of 10° to the right, and Control Group (CG) treated with pointing exercises, wearing neutral lenses which produce no effect on the visual field.

Independent variables (gender, age and education level) were collected for each participant. The MMSE was administered to exclude cognitive decline. All enrolled patients were assessed with specific batteries for neglect assessment and Bamford classification.

The two groups were evaluated at baseline (T0) and at the end (T1) after two weeks of treatment. All patients assigned to EG or CG was not informed of the effect of the lenses they were wearing during the treatment.

Treatment procedure

Prism Adaptation: Both groups of patients were exposed to two daily sessions of treatment from Monday to Friday over a period of 2

weeks with sessions lasting 20 minutes each, giving a total of 20 sessions.

According to the method presented by Rossettì and Frassinetti [20,23], patients were sitting at the table in front of a wooden box (height 30 cm, depth 34 cm in the middle and 18 cm at the edge, width 72 cm). The external edge on the patient side of the wooden box was straight while on the opposite side, facing the experimenter, the edge was convex. On the curved side there is a graduated line (in centimeters) with three possible positions: a central position straight ahead in front of the patient (0°) and a lateral position to the left or to the right of the patient's body midline (-21° and +21° respectively).

The wooden box was open on the front and on the rear side and the patient could operate the pointing movements towards a simple target like a pencil, showed by the therapist on the convex side. The targets were presented randomly in the central or in the lateral positions. The random sequence, previously defined, was the same for all the patients.

The patients were positioned in front of the box at a distance of 15 cm from the table. The therapist asked the patients to point with their index finger towards the target with the right arm starting every time from her/his chest at the level of the sternum (starting position), and to point the target with the index finger as fast as possible. The reaching movement was executed below the upper side of the box, in order to hide the arm's trajectory.

Each performance was recorded from the therapist on an appropriate form.

Each pointing task was performed in three different conditions: Pre-exposure, Exposure and Post-exposure.

Pre-exposure condition: At the beginning of the treatment, only during the first session, we asked the patients to point 60 targets randomly in one of the three possible positions (20 on the center, 20 on the right and 20 on the left) in order to train the patients to the procedure. Half of the 60 pointing are conducted with the visible hand and half are conducted with the hidden hand.

Starting from the second session, and for each following one, at the beginning of the treatment, we asked the patients to perform 30 pointing with the hidden hand in order to verify the after effect (the leftward visuomotor bias induced by prims) [20] or, in other words, what patients retained from the previous treatment.

Exposure condition: Patients were asked to point, as rapidly as possible with their right index finger, to 90 targets presented in random order in each of the three possible positions (30 on the center, 30 on the right and 30 on the left). All the pointing were performed wearing prismatic goggles inducing a 10° shift of the visual field to the right. All movements were performed with the arm below the top face of the wooden box in order to hide the arms' trajectory. The main goal of the Exposure Condition was to induce an adaptation to the rightward deviation. (Prism adaptation).

Post-exposure: The patients had to point 30 targets (10 on the center, 10 on the right and 10 on the left) without prism. The pointing was performed below the top of the box in order to hide the arm movement and also the index finger. The aim of this phase was to evaluate the persistence of the rightward deviation after the prism exposition (after effect).

Instruments

Neuropsychological tests

We administered the following battery of tests to the patients:

Bells Test: 315 small figures are randomly distributed on an A4 sheet. Patients have to select and tick the scattered 35 bells. The maximum score is 35 [29].

Behavioral Inattention Test-BIT: total score range from 0 to 146. The cut off is 129 points.

BIT sub tests: *Line crossing test:* 40 segments are randomly distributed with different inclination on an A4 sheet. Of these, 18 are on the left side of the sheet, 18 on the right side and 4 at the center. The patient has to cross out all lines on sheet. The maximum score is 36, as the four central lines are not counted.

Letter cancellation test: Patients have to cross out with a pencil all the letters "E" and "R" among a series of letters arranged in five rows on an A4 sheet. The maximum score for this test is 40 points (one point for each letter correctly crossed).

Star cancellation test: Patients have to cross out with a pencil all the small stars among letters, words, and larger stars distributed in scattered order on an A4 sheet. The maximum score is 54.

Figure and shape copying: The task is divided into two sub-tests. In the first subtest the patient has to copy three figures (a four-pointed star, a cube and a flower) vertically drawn on the left side of an A4 sheet. Each figure has to be copied on the corresponding quadrant on the right side. One point is given for each drawing copied in a symmetrical manner. The second sub-test consists in copying on another A4 sheet three geometric shapes (triangle, rectangle, rhombus divided in two, isosceles triangle). One point is given if the patients copy all three figures in the space below. The maximum total score is 4.

Line bisection: It consists in three lines of equal length drawn on an A4 sheet. The highest is shifted to the right, the lowest to the left and the intermediate to the center of the sheet. The patients have to halve the lines with a sign. The score, ranging from 0 to 3 points, depends on the distance of the patient's sign from the middle of each line. Maximum score is 9.

Representational drawing: The patient has to draw a clock, a human figure and a butterfly on three different sheets. The score, ranging from 0 to 1 for each drawing, depends on whether it is complete and symmetrical. 0 points if there are missing elements. The maximum score is 3 [30].

Clinical scales

Bamford Classification: It allows clustering patients with cerebral infarction into four groups on the basis of signs and symptoms according to some distinctive features.

Total anterior circulation infarcts (TACI): It involves the proximal stem of the middle cerebral artery. Patients present contralateral hemiplegia, hemianopsia and cognitive impairment.

Lacunar infarcts (LACI): It consists in occlusion of the deep perforating artery, with involvement of the lenticulo-striate arteries. These patients show hemiparesis, pure sensory deficit, dysarthria associated with deficient contralateral limb motor coordination and association of ataxia and hemiparesis.

Partial anterior circulation infarcts (PACI): produced by the occlusion of a branch of the middle cerebral artery with predominantly cortical involvement. Patients show motor, sensory and cognitive impairment.

Posterior circulation infarcts (POCI): It consists of the obstruction of the arteries in the vertebro-basilar territory. Patients could present bilateral motor and sensory deficits [31].

Functional scales

Behavioral Bergego Scale: This is a functional scale based on a direct observation of the patient's functional abilities in everyday activities, such as caring for hair and face, dressing or using a wheelchair. Each task scores from 0 to 3. The total score ranges from 0 (no disability) to 30 (severe disability) [32].

Statistical analysis

We used Wilcoxon test to compare the two groups according to age, gender, education level, onset days and neglect impairment. A mixed within subjects and between groups ANOVA was applied in order to compare the two groups of stroke patients at the enrollment time (T0) and after two weeks (T1) of pointing treatment with prisms (EG) or with neutral lenses (CG). Statistical analyses were carried out by the statistic center ICT-NHS of Grosseto, using the Statistical Package for Social Sciences software, version 18.0 (SPSS Inc, Chicago, IL).

Results

For the present study we enrolled 52 stroke patients, 33 males and 19 females, ranged from 36 to 83 years of age, with an average of 65.93 (SD=10.95). The average period of education was 9.95 years (SD=4.32). Patients were enrolled at an average of 1.99 months (DS=1.25) from stroke onset (Table 1).

	Gender	Age	Education (years)	Lesion site (Bamford)
EG1	F	60	12	LACI
EG2	M	53	17	LACI
EG3	M	66	13	LACI
EG4	M	74	8	TACI
EG5	M	60	17	TACI
EG6	M	60	8	PACI
EG7	M	64	5	PACI
EG8	M	68	5	TACI
EG9	M	67	13	TACI
EG10	F	82	4	PACI
EG11	F	65	5	PACI
EG12	M	53	13	PACI
EG13	F	74	11	LACI
EG14	M	78	missing data	PACI
EG15	M	71	missing data	PACI
EG16	M	62	13	PACI
EG17	F	68	missing data	LACI
EG18	F	50	17	TACI
EG19	M	74	17	TACI
EG20	M	79	5	LACI
EG21	M	83	5	LACI
EG22	M	48	13	LACI
EG23	M	77	8	PACI
CG1	M	52	8	TACI
CG2	M	60	13	LACI
CG3	M	74	13	PACI
CG4	M	73	8	TACI
CG5	M	66	13	TACI
CG6	F	70	5	TACI
CG7	M	73	5	PACI
CG8	M	59	11	PACI
CG9	M	67	5	PACI
CG10	F	56	13	PACI
CG11	M	36	13	PACI
CG12	F	61	5	PACI
CG13	F	79	5	TACI
CG14	M	57	5	LACI
CG15	F	61	8	TACI
CG16	M	66	13	PACI
CG17	F	56	16	TACI

Table 1: Reports a description of the sample (age, gender, education level and Bamford classification).

Due to their worsening clinical conditions, 2 patients assigned to EG and 4 patients assigned to CG did not complete the treatment so were excluded. Moreover we excluded 6 patients (3 patients in the EG group and 3 patients in the CG group) because of outliers. At the end the statistical analysis were conducted on a sample of 40 neglect patients (23 for EG and 17 for CG).

At the basal condition the two groups were comparable for age, gender, education, onset days, and neglect impairment measured with the Behavioral Inattention Test (Wilcoxon Z=-0,881 p=0.378) (Table 2).

Variable	group	average	st.dev	t	p

Age	CG	62.88	12.55	1.269	0.215
	EG	67.48	9.40		
Education	CG	9.35	3.92	0.777	0.443
	EG	1.45	4.67		
Onset from stroke (days)	CG	51.24	26.67	-1.261	0.215
	EG	66.30	43.52		
Bit-total score	CG	100.47	30.77	0.60	0.953

Table 2: Comparability of the two study groups.

Error reduction effect between groups

In order to verify the effect of prisms on neglect syndrome we evaluated the improvement in neuropsychological tests comparing the two groups before and after the treatment with a mixed within subjects and between groups ANOVA.

We have compared the EG and CG at T0 and T1 time, highlighting a correlation only with the timing. Indeed, data show that there is no significative correlation with the kind of treatment for all the outcome measures. At the Bells Test the within-subjects analysis shows that at T1 time, the number of targets for CG (T0=17.18+/-7.86; T1=22.24+/-8.05) and for EG (T0=22.65+/-7.25; T1=28.83+/-6.06), have significantly improved (F=32.45, p=0.000) (Figure 1). The analysis between groups shows no effect related to the kind of treatment (F=0.320, p=0.575).

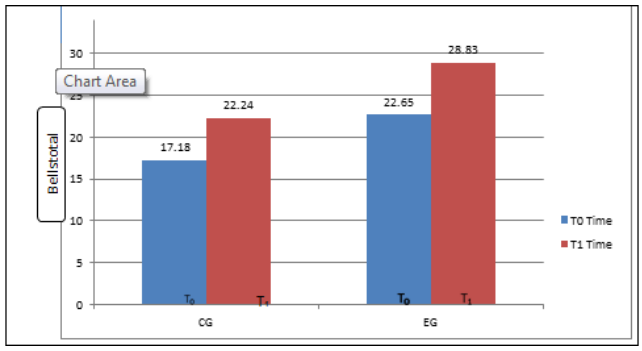

Figure 1: Bells total score at T0 and T1 time. Even if the difference between T0 and T1 time is significative for both groups (F=32.451, p=0.000), no significant effect related to the kind of treatment is found (F=0.320 p=0.575).

Also for the Behavioral Inattention Test the with-in subjects analysis shows that at T1 time, EG and CG have significantly improved their performance with respect to T0 time. The number of targets for both CG (T0=100.47+/-30.77; T1=112.12+/-30.09) and for EG (T0=99.87+/-32.13; T1=124.78+/-22.02) are significantly improved (F=22.033, p=0.000) (Figure 2).

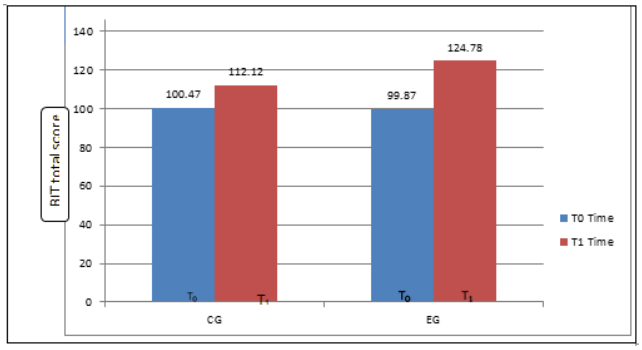

Figure 2: BIT total score at T0 and T1 time. Even if the difference between the times of treatment (T0-T1) is significative for both groups (F=22.033, p=0.000), no significant effect related to the kind of treatment is found (F=2.936 p=0.095).

Between groups analysis shows no effect related to the prisms treatment (F=2.936 p=0.095).

The Bergego scale with-in subjects analysis shows that at T1 time, EG and CG have significantly improved their performance respect to T0 time. The number of targets both for CG (T0=17.00+/-9.825; T1=11.56+/-8.222) and for EG (T0=17.77+/-7.224; T1=9.45+/-7.156) are significantly improved (F=25.354, p=0.000) (Figure 3). The analysis between groups show no significant effect related to prisms treatment (F=1.112 p=0.299).

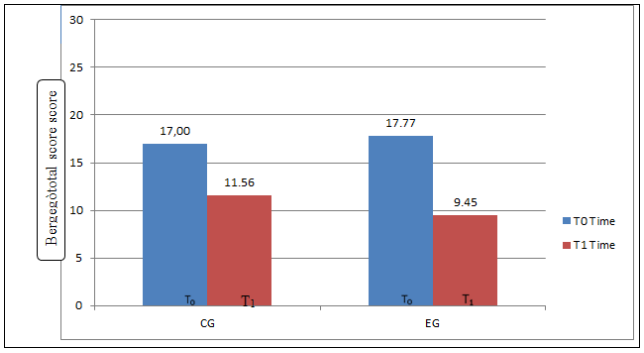

Figure 3: Bergego total score at T0 and T1 time. Even if the difference between the times of treatment (T0-T1) is significative for both groups (F=25.35, p=0.000), between groups analysis show no significant effect related to the kind of treatment (F=1.112 p=0.299).

Discussion

In a previous random single blind study [33] we compared neutral lenses with 10 dioptric prismatic lenses that produce a deviation of 5 degrees of the fixation point of visual field toward the right side, in order to verify if it was possible to obtain a therapeutic effect with less discomfort to patients. Since we obtained the same improvement for both groups (5 prismatic dioptric lenses and neutral lenses), we concluded that prisms of less than 10 dioptric degrees did not produce any therapeutic effect, while the improvement of both groups was considered as a result of the pointing exercises.

In this study, we used the same procedure, as described by Frassinetti and coworkers [20], comparing neutral lenses with 20 dioptric prismatic lenses that produce a deviation of degrees of fixation point of visual field toward the right side.

Comparing two groups at the T0 and T1 times, both groups show a significant improvement in administered neuropsychological tests, but the analysis between groups highlights that this effect can be related to the time of treatment rather than to the group (prisms or neutral lenses).

In the last 10 years, many papers have highlighted the effectiveness of prisms treatment [23,34] but others researchers have highlighted opposite conclusions from their data [35].

Among the studies in which we can observe an improvement induced by pointing using hidden limb and prismatic lenses, Dijkerman and colleagues reported an improvement of somatosensorial function in a patient, a 31-years-old, right-handed woman, included in the study after 3 months from the onset of an ischemic stroke [36]. In this work, unfortunately, the main aim was only to exclude spontaneous improvements so we cannot understand if a similar result could be obtained also without prismatic lenses.

Farné and colleagues studied 6 subjects with neglect, finding improvements in both the tasks they used, which required the combined use of eyes and hands. Unfortunately, also in this case, there was not a control group treated with neutral lenses, so we cannot attribute the observed effect to the prismatic lenses rather than to the pointing training [37].

Rode and colleagues evaluated the effect of the training on 2 patients treated with prisms, on a drawing copy and on representational tasks. The data highlighted a significant improvement on both the tasks, but also in this case, the treatment was not compared with neutral lenses treatment [39].

Frassinetti and colleagues in 2002, evaluated 7 subjects treated with prismatic lenses compared with 6 untreated patients in order to exclude that their improvement was only due to a spontaneous evolution. The authors concluded that the improvement was due to the prismatic lenses, but also in this study the prisms treatment was not compared with neutral lenses treatment [20].

As in our previous study, other researchers have highlighted a significant improvement in neglect impairment using both neutral lenses and prisms, but also in these cases the prisms power was lower than 10 prismatic dioptrics [39].

In 2006, Rousseaux and coworkers, involved 10 neglect patients randomly treated with prismatic or neutral lenses. The results highlighted a significant neglect improvement in both groups without statistical differences between the two groups. The authors argue that the effect of the improvement observed could be related to a learning effect or to an increase in vigilance or sustained attention [21].

In 2009 Serino compared 10 neglect patients treated with prisms, and 10 neglect patients treated with neutral lenses, highlighting an improvement for both groups, but higher for prisms. The authors explained the improvement observed for the neutral lenses group as a consequence of the procedure that requires the patient to plan and perform a series of movements toward a visual stimulus, which is occasionally placed within the neglected field [40].

Làdavas and colleagues in 2011, administered the pointing exercise comparing two types of prisms treatments based on two different procedures consisting of the presence or absence of visual feedback in target pointing. These two methods were also compared with neutral lenses. The results highlighted that the repetition of pointing movements toward visual stimuli can improve visuospatial performance both in patients treated with prisms and with neutral lenses. Neglect amelioration was significantly greater when the pointing was performed under the influence of prisms. The application of the procedure named "Terminal Exposure" (i.e. the patient cannot see his/her hand before the movement has reached its end) highlighted the importance of hiding the arm movement during the pointing task [34].

To explain the discrepancy in the results from literature we have hypothesized that it could depend on one or more of the following hypotheses:

- different assessment tools used by the researchers
- different application of the prisms method
- differences between enrolled patients

Different assessment tools

Literature seems to show that the effectiveness of this type of treatment (pointing with non-visible limb and prismatic lenses) is remarkable and probably has a beneficial effect on the different neglect symptoms also (e.g. on visual perceptive ones). Indeed, Rode has found that it seems to be effective on representational neglect [38], Silicate on postural imbalance [41], Dijkerman on somatosensory function [36], and Maravita on tactile and auditory extinction [42]. All these articles

show that the prisms seem to be effective on a large number of neglect symptoms. It seems unlikely that the effect can be related to the type of task used to highlight the prisms' effectiveness. Moreover, Farnè and colleagues in 2002 conducted a research study using tasks requiring the simultaneous use of eyes and hands compared with tasks that required the only use of vision (the use of the hand was strongly inhibited when indicating the pictures that they were describing or the words they were reading). Comparing the performance of 6 neglect patients before and after only one session of treatment with prismatic lenses, the researchers observed a significant improvement on both types of tests. This could lead the authors to assume that probably the prisms treatment produces an effect on higher levels of visual-spatial elaboration, given that the cognitive functions required for the correct execution of the proposed tasks are very different [37].

Different application of prisms method

It has been proposed by some researchers [34] that the different results can be attributed to the way in which the researchers apply the method. This seems to be confirmed by some articles that show that 10 prismatic dioptric lenses are useless to promote significant difference if compared with neutral lenses [33,39]. Moreover, Làdavas and colleagues underlined the differences in applying the method with very late visual feedback in target pointing, compared with visible arm during the pointing movement, highlighting how a better improvement can be obtained with the hidden arm during the pointing movement. However this does not seem to be coherent with the results highlighted in this study as we have exactly applied the method described by Rossettì and Frassinetti [20,23].

Differences between enrolled patients

Finally, the type of patients normally involved may account for the differences between the results reported in the different papers. Serino has tried to study behavioral and neuroanatomical predictors of recovery exploring the reorganization of low-order visual-motor behaviors and high-order visual-spatial representation induced by prisms [43]. There is no correlation between the reduction of errors and the after-effect, which suggests that these two are correlated by an unknown process [44], while the reduction of errors during the first week can predict an improvement in neglect over time, as well as a greater ability to quickly adapt to the deviation induced by prisms.

Regarding the neuroanatomical predictors, the extent of the brain lesion seems to be associated with a lower improvement [45]. Medial temporal structures play an important role in supporting functional improvement after prism adaptation treatment [46] and anterior cerebellar cortex in computation or compensation of ipsidirectional visual error [47]. Moreover, severe occipital lesions were associated with a lack of error reduction, poor neglect recovery and reduced oculo-motor system amelioration [43]. We can assume that the impairment of greater cortical areas can reduce the restoration of the higher levels, requiring greater integration, such as visuospatial representation. While prisms could be effective on these high levels of visuomotor behavior, the lower-order could be mediated by the pointing training with no visible limb [43]. Moreover, since pointing relies on a form of visuomotor coordination between hand and eye [48] pointing exercises might train the patient to orient the eye-hand sensory motor system toward the left side of space. This effect can be strongly reinforced by prism adaptation [36].

Our results show a significant improvement of both groups throughout the treatment time. Even if it is not possible to demonstrate a significant difference between the two groups, data show a higher improvement of the EG in all the outcome measures.

As in this study we have applied the method described by Frassinetti and coworkers in 2002, we believe that the differences between our results and those reported in other studies with a more evident prisms effect can neither be due to the applied treatment nor to the outcome measures used for the evaluation, but probably it can be correlated with the gravity of the enrolled patients in our sample [43,45].

Conclusions

According to our results we can conclude that pointing with no visible arm is useful in neglect treatment and that prisms procedure produces some further benefits even if the low number of subjects enrolled is still insufficient to give clear evidence in the use of prisms. However, as reported from literature, since no adverse effects related to the use of prisms has ever been reported, it is preferable to choose this procedure to improve neglect symptoms in clinical settings.

References

1. Husain M, Mattingley JB, Rorden C, Kennard C, Driver J (2000) Distinguishing sensory and motor biases in parietal and frontal neglect. Brain 123: 1643-1659.
2. Ringman JM, Saver JL, Woolson RF, Clarke WR, Adams HP (2004) Frequency, risk factors, anatomy, and course of unilateral neglect in an acute stroke cohort. Neurology 63: 468-474.
3. Bartolomeo P, Thiebaut de Schotten M, Doricchi F (2007) Left unilateral neglect as a disconnection syndrome. Cereb Cortex 17: 2479-2490.
4. Doricchi F, Thiebaut de Schotten, M Tomaiuolo, F Bartolomeo (2008) White matter (dis)connections and gray matter (dys)functions in visual neglect: gaining insights into the brain networks of spatial awareness. Cortex 44: 983-995.
5. Karnath HO (2001) New insights into the functions of the superior temporal cortex. Nat Rev Neurosci 2: 568–576.
6. Buxbaum LJ, Ferraro MK, Veramonti T, Veramonti T, Farne A, et al. (2004) Hemispatial neglect: Subtypes, neuroanatomy, and disability. Neurology 62: 749-756.
7. Heilman K, Watson RT, Valenstein E (1993) Neglect and related disorders. Clinical Neuropsychology pp. 279-336.
8. Nijboer TC, Kollen BJ, Kwakkel G (2013) Time course of visuo spatial neglect early after stroke: a longitudinal cohort study. Cortex 49 : 2021-2027.
9. Nijboer TC, Kollen BJ, Kwakkel G (2014) The impact of recovery of visuo-spatial neglect on motor recovery of the upper paretic limb after stroke. PLoSONE 9: e100584.
10. Stone SP, Halligan PW, Greenwood RJ (1993) The incidence of neglect phenomena and related disorders in patients with an acute right or left hemispherestroke. Age ageing 22: 46-52.
11. Gainotti G, Giustolisi L, Nocentini U (1990) Controlateral and ipsilateraldisoredrs of visual attention in patients with unilateral brain damage. J Neurol Neurosurg Psychiatry 53 : 422-426.
12. Suchan J, Rorden C, Kernath HO (2012) Neglect severity after left and right brain damage. Neuropsychologia 50 : 1136-1141.
13. Denes G, Semenza C, Stoppa E, Lis A (1982) Unilateral spatial neglect and recovery from hemiplegia: a follow-up study. Brain : 105: 543-552.
14. Jehkonen M, Ahonen JP, Dastidar P, Koivisto AM, Laippala P, et al. (2000) Visual neglect as a predictor of functional outcome one year after stroke. Acta NeurolScand 101: 195-201.
15. Mutai H, FurukawaT, Araki K, Misawa K, Hanihara T (2012) Factors associated with functional recovery and home discharge in stroke patients

admitted to a convalescent rehabilitation ward. Geriatr Gerontol Int 12 : 215-222.

16. Appelros P, Karlsson GM, Seiger A, Nydevik I (2003) Prognosis for patients with neglect and anosognosia with special reference to cognitive impairment. J Rehabil Med 35: 254-258.
17. Gialanella B, Monguzzi V, Santoro R, Rocchi S (2005) Functional Recovery after hemiplegia in patients with neglect: the rehabilitative role of anosognosia. Stroke 36: 2687-2690.
18. Paolucci S, Antonucci G, Gialloreti LE, Traballesi M, Lubich S, et al. (1996) Predicting Stroke Inpatient Rehabilitation Outcome: The Prominent Role of Neuropsychological Disorders. Eur Neurol 36: 385-390.
19. Luauté J, Michel C, Rode G, Pisella L, Jacquin-Courtois S, et al. (2006) Functional anatomy of the therapeutic effects of prism adaptation on left neglect. Neurology 66: 1859-1867.
20. Frassinetti F, Angeli V, Meneghello F, Avanzi S, Làdavas E (2002) Long lasting amelioration of visuospatial neglect by prism adaptation. Brain 125: 608-623.
21. Rousseaux M, Bernati T, Saj A, Kozlowski O (2006) Ineffectiveness of prism adaptation on spatial neglect signs. Stroke 37 : 542-543.
22. Angeli V, Benassi MG, Làdavas E (2004) Recovery of oculo-motor bias in neglect patients after prism adaptation. Neuropsychologia 42: 1223-1234.
23. Rossetti Y, Rode G, Pisella L, Farnè A, Boisson D, et al. (1998) Prism adaptation to a right ward optical deviation rehabilitates lefth emispatial neglect. Nature 395: 166-169.
24. Shiraishi H, Yamakawa Y, Itou A, Muraki T, Asada T (2008). Long-term effects of prism adaptation on chronic neglect after stroke. NeuroRehabilitation 23 : 137-151.
25. Rusconi ML, Carelli L (2012) Long-term efficacy of prism adaptation on spatial neglect: preliminary results on different spatial components. ScientificWorldJournal 2012 : 618528.
26. Luauté J, Halligan P, Rode Gilles, Rossettì Y, Boisson D (2006) Visuo-spatial neglect : a systematic review of current interventions and their effectiveness. Neurosci Biobehav Rev 30 : 961-982.
27. Barrett AM, Buxbaum LJ, Coslett HB, Edwards E, Heilman KM, et al. (2006) Cognitive Rehabilitation Interventions for Neglect and Related Disorders: Moving from Bench to Bedside in Stroke Patients. J Cogn Neurosci 18: 1223-1236.
28. Jacquin-Courtois JS, Rode G, Pavani F, O'Shea J, Giard MH, et al. (2010) Effect of prism adaptation on left dichotic listening deficit in neglect patients: glasses to hear better. Brain 133: 895-908.
29. Gauthier L, Dehaut F, Joanette Y (1989) The Bells test: A quantitative and qualitative test for visual neglect. International Journal of Clinical Neuropsychology 11: 49-54.
30. Wilson B, Cockburn J, Halligan P (1987) Development of a behavioural test of visuo-spatial neglect. Arch Phys Med Rehabil 68 : 98-102.
31. Bamford J, Sandercock P, Dennis M, Burn J, Warlow C (1991) Classification and natural history of clinically identifiable subtypes of cerebral infarction. Lancet 337: 1521-1526.
32. Bergegò C, Azouvi P, Samuel C, Marchal F, Dreyfusa L, et al. (1995) Validation d'une échelle d'évaluation fontionelle de l'hémineglígence dans la vie quotidienne: l'échelle CB. Ann Réad Méd Phys 96: 183-189.
33. Mancuso M, Pacini M, Gemignani P, Bartalini B, Agpstini B, et al. (2012) Clinical application of prismaticlenses in the rehabilitation of neglect patients. A randomizedcontrolled trial. Eur J Phys Rehabil Med 48: 197-208.
34. Làdavas E, Bonifazi S, Catena L, Serino A (2011) Neglect rehabilitation by prism adaptation: different procedures have different impacts. Neuropsychologia 49: 1136-1145.
35. Bowen A, Lincoln N (2008) Cognitive rehabilitation for spatial neglect following stroke. Cochrane.
36. Dijkerman HC, Webeling M, Walter JM, Groet E, Van Zandvoort MJ (2004) A long-lasting improvement of somatosensory function after prism adaptation, a case study. Neuropsychologia 42: 1697-1702.
37. Farnè A, Rossetti Y, Toniolo S, Làdavas E (2002) Ameliorating neglect with prism adaptation: visuo-manual and visuo-verbal measures. Neuropsychologia 407: 718-729.
38. Rode G, Rossetti Y, Boisson D (2001) Prism adaptation improves representational neglect. Neuropsychologia 39: 1250-1254.
39. Turton A, O'Leary K, Gabb J, Woodward R, Gilchrist I (2010) A single blinded randomised controlled pilot trial of prism adaptation for improving self-care in stroke patients with neglect. Neuropsychol Rehabil 20: 180-196.
40. Serino A, Barbiani M, Rinaldesi L, Làdavas E (2009) Effectiveness of Prism Adaptation in Neglect Rehabilitation A Controlled Trial Study. Stroke 40: 1392-1398.
41. Tilikete C, Rode G, Rossetti Y, Pichon J, Li L, et al. (2001) Prism adaptation to rightward optical deviation improves postural imbalance in left-hemiparetic patients. Current Biology 11: 524-528.
42. Maravita A, McNeil J, Malhotra P, Greenwood R, Husain M, et al. (2003) Prism adaptation canimprove contralesional tactile perception in neglect. Neurology 60: 1829-1831.
43. Serino A, Angeli V, Frassinetti F, Làdavas E (2006) Mecfhanisms underlying neglect recovery after prism adaptation. Neuropsychologia 44: 1068-1078.
44. Redding GM, Wallace B (1993) Adaptive coordination and alignment of eye and hand. J Mot Behav 25: 75-88.
45. Chechalacz M, Rotshtein P, Roberts KL, Bickerton WL, Lau JKL, et al. (2012) The prognosis of allocentric and egocentric neglect: evidence from clinical scans. PLoSONE 7: e47821.
46. Chen P, Goedert K, Shah P, Foundas A, Barret A (2014) Integrity of medial temporal structures may predict better improvement of spatial neglect with prism adaptation treatment. Brain Imaging Behav 8: 346-358.
47. Pisella L, Rossetti Y, Michel C, Rode G, Boisson D, et al. (2005) Ipsidirectional impairment of prism adaptation after unilateral lesion of anterior cerebellum. Neurology 65: 150-152.
48. Neggers SF, Bekkering H (2000) Ocular gaze is anchored to the target of an ongoing pointing movement. J Neurophysiol 83: 639-651.

This article was originally published in a special issue, entitled: **"Neuroscience and Rehabilitation",** Edited by Fuminari Kaneko, Sapporo Medical University, Japan and Tadayoshi Asaka, Hokkaido University, Japan