CHAPTER 17

Bottom-up transfer of sensory-motor plasticity to recovery of spatial cognition: visuomotor adaptation and spatial neglect

Gilles Rode 1,2,3,∗, Laure Pisella 1,3, Yves Rossetti 1,2,3, Alessandro Farnè 1 and Dominique Boisson 1,2,3

1 Espace et Action, Institut National de la Santé et de la Recherche Médicale, Unité 534, 16 avenue Lépine, Case 13, 69676 Bron, France
2 Service de Rééducation Neurologique, Hôpital Henry Gabrielle, Hospices Civils de Lyon et Université Claude Bernard, Lyon, France
3 Institut Fédératif des Neurosciences de Lyon, Lyon, France

Abstract: A large proportion of right-hemisphere stroke patients show hemispatial neglect, a neurological deficit of perception, attention, representation, and/or performing actions within their left-sided space, inducing many functional debilitating effects on everyday life, and responsible for poor functional recovery and ability to benefit from treatment. This spatial cognition disorder affects the orientation of behavior with a shift of proprioceptive representations toward the lesion side. This shift is similar to that produced by psychophysical manipulations as a wedge-prism exposure in normal healthy subjects. In both subjects, one major compensative effect of short-term prism adaptation is a shift of proprioceptive representations, demonstrated by a shift in manual straight-ahead pointing in the dark, in a direction opposite to the visual shift. In neglect patients, prism adaptation involves the shift of proprioceptive representations to the left with a reduction of rightward bias observed in neglect patients in visuo-manual tasks as line-bisection, line-cancellation or copy drawing. Improvement of neglect is also observed in no visuo-manual tasks as mental imagery, auditory extinction or posture. This generalization of prism adaptation effects at different neglect level symptoms suggests that the process of prism adaptation may activate brain functions related to multisensory integration and higher spatial representations. Moreover the positive effects found for both sensorimotor and more cognitive spatial functions lasted for at least two or more hours after prism removal. Unlike reduction of neglect through sensory stimulations, the long-lasting improvement of neglect after prism adaptation suggests the activation of short-term plasticity of brain functions related to coordinate transformations and space representations. Lastly, the duration of these effects could be useful in rehabilitation programs, as suggested by the effects of prism adaptation on disabling neglect symptoms as wheelchair driving, posture or writing.

Neglect, an oriented-space-behavior disorder

Hemispatial neglect is defined as the patient’s failure to report, respond to, or orient toward novel and/or meaningful stimuli presented to the side opposite to the brain lesion (Heilman et al., 1985). Chronic neglect is most frequently consecutive to the damage of the right brain hemisphere. For example, neglect patients can forget to read the left part of a journal or a book, omit to eat the left half of a plate, forget to shave the left hemiface, or hit obstacles on the left. Associated with contralateral hemiplegia, hemianesthesia and hemianopia, chronic neglect worsens the severity of these motor-

∗Correspondence to: G. Rode, Service de Rééducation Neurologique, Hôpital Henry Gabrielle, Hospices Civils de Lyon and Université Claude Bernard, route de Vourles, BP 57, F-69565 St Genis-laval, France. Tel.: +33-478-86-50-23; Fax: +33-478-86-50-30; E-mail: gilles.rode@chu-lyon.fr
or sensory-associated deficits inducing many functionally debilitating effects on everyday life, and is responsible for poor functional recovery and ability to benefit from treatment (Denes et al., 1982; Fullerton et al., 1986; Halligan et al., 1989; see also Vallar et al., 2003, this volume) (Fig. 1).

For these reasons, many attempts have been made in the last 20 years to rehabilitate neglect. Different approaches have been proposed relying mainly on passive physiological stimulations or active training (see review in Rossetti and Rode, 2002). The main goal of these methods is to favor the re-orientation of the motor behavior toward the neglected side and the first difficulty is to obtain a generalization of the effects at a functional level.

Hemispatial neglect is a disorder of spatial orientation in which the behavior is biased to the side of the lesion. This bias may be demonstrated by the clinical observation of patients or by simple tests such as a line bisection task. It may also be illustrated in patients by the shift of straight-ahead pointing in the dark, and has been even interpreted as an impairment of the transformation of sensory input into motor output (Jeannerod and Biguer, 1987). This hypothesis, also called 'egocentric reference', is compatible with current knowledge about the crucial role of the parietal cortex in coordinate transformation (reviews: Jeannerod and Rossetti, 1993; Andersen, 1995; Milner and Goodale, 1995; Pisella and Rossetti, 2000; Rossetti and Pisella, 2002). The prediction made by Jeannerod and Biguer (1987) was that unilateral lesions "produce an illusory 'rotation' of the egocentric reference, somewhat as if the subject felt being constantly rotated toward the lesion side." This idea has been recently revisited by Karnath (1997) and Vallar et al. (1997), who proposed that the coordinate transformation system was biased by an internal constant error with a translation or a rotation of the egocentric spatial frame. It has also been challenged by several recent observations (Farnè et al., 1998; Bartolomeo and Chokron, 1999; Pisella et al., 2002).

**Shift of proprioceptive representations after prism adaptation**

It is interesting that a similar shift in manual straight-ahead pointing may be produced by psychophysical manipulations in normal healthy subjects (Jeannerod and Rossetti, 1993). For example, exposure to an optical alteration of the visual field is known to produce an initial disorganization of visuo-motor behavior, which can be corrected through visuo-motor adaptation. Such adaptation has been widely used to demonstrate the plasticity of coordinate transformations involved in multisensory and sensorimotor integration. One major compensative effect of short-term wedge-prism exposure is a shift of proprioceptive representations, which can be demonstrated by a shift in manual straight-ahead pointing in the dark, in a direction opposite to the visual shift produced by the prisms. This shift appears similar to that showed by neglect patients and one may therefore wonder whether the egocentric reference of patients with spatial neglect could be altered by prism adaptation, and whether a hypothetical shift can be accompanied by an improvement of other neglect symptoms.

**Reduction of egocentric reference shift after prism adaptation in neglect**

The adaptability of neglect patients to a right lateral shift of visual field (induced by a simple target-pointing task with base-left wedge prisms) was thus evaluated (for details see Rossetti et al., 1998a,b) with the measure of manual body-midline demonstration. Patients produced 10 straight-ahead pointing trials before and after a short period of adaptation. A group of five healthy control subjects was also tested in the same conditions. The amount of visual displacement was set at 10 degrees, chosen as being the best compromise between a significant shift, required to generate adaptation, and visual comfort.
(stronger displacement being responsible for curvature distortion and color fringes). The procedure used to generate the adaptation was simply to require the patients to perform 60 pointing movements to visual targets presented in front of them. Attention was paid to keeping the head straight throughout the testing and the adaptation procedure, and to prevent any view of the hand at its starting position. Patients were then always tested without the prismatic goggles.

As in several previous studies, the patient’s mean straight-ahead was initially shifted to the right. Following the adaptation, both patients and controls demonstrated relative straight-ahead shifts to the left. These results demonstrated that neglect patients can easily adapt to a lateral shift of the visual field to the right, and that prism adaptation, acting against the rightward bias of straight-ahead demonstration allows these patients to show a close-to-normal post-test performance. Moreover the results showed also that the amount of the prism after-effect was about twice that of normals (Fig. 2a).

Recent studies have shown that this and other prism adaptation after-effects can be sustained over several days in patients (Farnè et al., 2002; Frassinetti et al., 2002; Pisella et al., 2002) (Fig. 2b).

**Improvement of neglect symptoms after prism adaptation**

The main question was whether the straight-ahead shift to the left produced by prism adaptation may be associated to a reduction of rightward bias observed in neglect patients in visuo-manual tasks.

Fig. 2. Shift of straight-ahead pointing after prism adaptation. (a) Comparison of the amplitude of the immediate after-effects in a group of neglect patients and a control group. Blindfolded subjects were required to point straight ahead while their head was kept aligned with the body's sagittal axis. Ten pointing trials were run in the pre-test (without goggles) and in the post-test (immediately upon the 10° prism (white arrow) removal). As expected, the midline demonstrations made by the neglect group were initially shifted to the right, whereas control subjects pointed to their actual straight-ahead. Patients were more affected by the adaptation than controls (black arrows), and the magnitude of this effect was less variable in patients (arrow whiskers), (from Rossetti et al., 1998a). (b) Longitudinal study of the evolution of the straight-ahead after prism adaptation in two neglect patients: temporal evolution of the performance of two neglect patients (SA and PE) in a straight-ahead pointing task. Blindfolded subjects were required to point straight ahead while their head was kept aligned with the body's sagittal axis. Ten pointing trials were run in the pre-test (without goggles) and in the post-test (immediately upon the 10° prism removal) and late-tests (Day 2–Day 4). Positive values correspond to right deviations, and negative ones to left deviations. The shadowed area represents the pretesting period gathering the two sessions realized by the patients before a single prism adaptation procedure. The x-axis zero corresponds to the experimental testing performed just after adaptation (upon prism removal). In the late-tests, the performance of patient PE seemed to be stabilized around the normal value. By contrast, patient SA did not show a long-term improvement with respect to the demonstration performed prior to prism adaptation. (From Pisella et al., 2002.)

It would seem logical that the effects of prism adaptation should be restricted to, or best for, visuo-motor tasks, because they have more common features with the visuo-manual adaptation procedure. In the original study, we observed that the best improvement was observed for the Schenckenberg bisection test (6/6 patients markedly improved), whereas the weakest improvement was obtained for text reading (2/6 patients markedly improved). Therefore other tests of neglect were investigated (Table 1).

Rode et al. (1998, 2001a) explored the effect of prism adaptation on visual imagery and found a clear-cut improvement in two patients who could initially not evoke cities on the western half of an internally generated map of France (Fig. 4a). This result strongly suggested that the after-effects of vi-
suo-manual adaptation can no longer be considered to be restricted to visual and motor parameters (Rossetti et al., 1999a).

Farnè et al. (2002) compared visuo-motor tasks (including line and bell cancellation tests, and two sub-tests taken from the Behavioral Inattention Test (B.I.T) battery, namely letter cancellation and line bisection) with visuo-verbal tasks (the visual scanning test, also taken from the B.I.T. (Wilson et al., 1987), requiring a verbal description of the objects depicted on a colored picture; an object-naming task with 30 Snodgrass pictures of familiar objects intermingled with geometric shapes as distracters; word and non-word reading), in six patients. They observed that
TABLE 1
Different symptoms of hemispatial neglect alleviated by prism adaptation and duration of improvement

<table>
<thead>
<tr>
<th>Symptoms of neglect</th>
<th>Duration of improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visuo-spatial neglect</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Object-centered neglect</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Space-centered neglect</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Personal neglect</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Representational neglect</td>
<td>immediate</td>
</tr>
<tr>
<td>Subjective straight-ahead shift</td>
<td>96 h</td>
</tr>
<tr>
<td>Motor reaction time</td>
<td>immediate</td>
</tr>
<tr>
<td>Left auditory extinction</td>
<td>immediate</td>
</tr>
<tr>
<td>Haptic neglect</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Ocular scanning</td>
<td>≥ 2 h</td>
</tr>
</tbody>
</table>

**Functional disabilities**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheelchair driving</td>
<td>≥ 96 h</td>
</tr>
<tr>
<td>Postural instability</td>
<td>immediate</td>
</tr>
<tr>
<td>Reading</td>
<td>≥ 2 h</td>
</tr>
<tr>
<td>Writing (unpublished results)</td>
<td>≥ 2 h</td>
</tr>
</tbody>
</table>

*a* Rossetti et al., 1998a,b.
*b* Rode et al., 1999.
*c* Courtois-Jacquin et al., 1999.
*d* Luauté et al., 2000.
*e* Rode et al., 2000.
*f* Pisella et al., 2002.
*g* Farnè et al., 2002.
*h* McIntosh et al., 2001.
*i* Tilikete et al., 2001.
*j* Rode et al., 2001a,b.
*k* Courtois-Jacquin et al., 2001.
*l* Toutounji et al., 2001.
*m* Dijkerman et al., 2002.
*n* Frassinetti et al., 2002.

The fact that other sensory modalities can be improved [haptic circle centering (McIntosh et al.,...]

---

**Fig. 3. Effect of prism adaptation on hemispatial neglect assessed by visuo-motor tasks.**

(a) Copying test (Gainotti et al., 1972) performed by a patient group exposed to prism adaptation and a control group. The figure shows the mean number of items drawn symmetrically (+ s.e.m.) in the two groups. The score is improved in the ‘prisms’ group and the performance increases between the post-test and the late-test. (Derived from Rossetti et al., 1998a.)

(b) Drawing from memory. Effect of prism adaptation on free drawing of object (clockwise) in a neglect patient (M.G.) prior to prism exposure (pre-test) and after a delay of about 1 h (post-test) and 48 h (late-test).
Fig. 4. Effect of prism adaptation on hemispatial neglect assessed by non-visuo-motor tasks. (a) Mental imagery. Maps of France plotted from the mental evocation of the patient prior to a prism exposure (pre-test) and immediately after removing the goggles (post-test). The filled circles indicate the geographical loci of the different responses and the bold number indicates the total number of responses. (From Rode et al., 2001a,b.) (b) Auditory extinction. Improvement of left auditory extinction assessed by dichotic listening test after prism adaptation in two neglect patients. The difference of correct responses percentage between the right and the left ear is dramatically reduced after the prism adaptation period, suggesting that a simple visuo-manual adaptation task may influence the orientation of attention in other sensory modalities. (From Courtois-Jacquin et al., 2001.)
2001), dichotic listening (Courtois-Jacquin et al., 2001), haptic object recognition (Toutounji et al., 2001) and that several non-manual tasks [postural control (Tilikete et al., 2001), wheelchair driving (Jacquin et al., 1998; Rossetti et al., 1999b), imagery (Rode et al., 1998, 2001b), verbal reports in a Temporal Order Judgement task (Pisella and Mattingley, 2002)] were also improved suggests that the effects of prism adaptation are not restricted to visuo-manual parameters as they are known to be in normal subjects. These results strongly suggest that adaptation to wedge prisms somehow affects the very core of hemispatial neglect (see also Michel et al., 2002).

Possible explanations of prism adaptation action on neglect

If prism adaptation can improve numerous aspects of neglect, then the possible mechanisms of this improvement are worth investigating because they could help us develop a comprehensive description of neglect physio-pathology and hence facilitate the development of more refined methods of rehabilitation. One obvious candidate would be the effect of prisms on the patient's egocentric reference, as it provided the rationale for initiating this series of experiments. However, Pisella et al. (2002) showed that there was no significant correlation between the effect of prisms on manual straight-ahead pointing and on line bisection performance. Furthermore they reported that these two parameters could be affected in contrasting ways by prism adaptation, such that a dynamic double dissociation could be observed in the long-term effects. This result not only confirmed the dissociability between the egocentric reference frame and other aspects of neglect (Farnè et al., 1998; Bartolomeo and Chokron, 1999), but they also excluded a possible direct causal role of the sensory-motor after-effects of prisms on the general spatial deficit exhibited by the patients.

Another explanation for the effects of adaptation on the patients’ deficits would be the existence of possible cross-talk or synergy between the short-term plasticity mechanisms involved in the adaptation, and the longer-term plasticity mechanisms involved in recovery. This hypothesis was explored by Luauté et al. (2000) who compared the effects of left- versus right-deviating prisms. Because the sensory-motor after-effects produced by these two types of wedge prisms are symmetrical in normals, one might predict that they should generate a similar amount of plasticity and thus affect hemispatial neglect in the same way. However, adaptation to left-sided visual displacement did not improve a group of five patients. As for the question of specificity, this result also demonstrated that non-lateralized parameters such as arousal could not account for the effect of adaptation (Rossetti and Rode, 2002). Moreover, the lack of effect on spatial cognition in conditions of pointing with neutral goggles (Rossetti et al., 1998) or passive exposure to prisms (Colet et al., 2000) reinforced the idea of a specific effect of prism adaptation on neglect.

Prism adaptation in normal subjects produces visual after-effects of similar amplitudes, regardless of the left or the right direction of the prismatic shift (e.g. Welsch, 1986; Redding and Wallace, 1992). Therefore, the asymmetrical after-effects observed on line bisection tasks cannot simply be explained away as the product of symmetrical visual after-effects. Moreover, visual after-effects are known to occur in the same direction as the prismatic deviation (e.g. Welsch, 1986; Redding and Wallace, 1992), whereas the perceptive and cognitive after-effects are observed in the opposite direction (rightward prisms allow neglect patients to explore further to the left space).

Lastly, in one left neglect patient, an improvement of leftward ocular scanning was evidenced following prism adaptation without correlated reduction of the size underestimation of the left stimulus (Dijkerman et al., 2002). These preliminary results suggest that the effects of prism adaptation on spatial cognition may not be mediated by a modification of ocular scanning but rather by higher-level effects.

The last candidate mechanism is obviously associated with the attentional theory of neglect. Preliminary results from Pisella et al. (unpublished data) suggested that the strong left–right attentional gradient observed in neglect patients could be reduced following prism adaptation. Another pure attentional deficit as sensory extinction could also be improved after prism adaptation. In six right-brain damaged patients with left visuo-spatial neglect and auditory extinction, prism adaptation involved an improvement of both visuo-spatial deficit and auditory extinction.
TABLE 2

<table>
<thead>
<tr>
<th>Cases</th>
<th>LRT before</th>
<th>LRT after</th>
<th>RRT before</th>
<th>RRT after</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAC</td>
<td>584</td>
<td>381</td>
<td>523</td>
<td>438</td>
</tr>
<tr>
<td>HAY</td>
<td>629</td>
<td>481</td>
<td>521</td>
<td>587</td>
</tr>
</tbody>
</table>

Two left neglect patients (cases HAC and HAY) were asked to reach and grasp an object (tennis ball) placed on their sagittal axis and then throw it in a left or a right basket; they were slower to initiate their movement to the left side as compared to the right. These results suggest that anticipation of the ultimate goal of an action led to a retrograde transfer of neglect onto action elements which have no left-right component by themselves. No comparable effect was found in two left brain-damaged patients and two control subjects. Abbreviations: LRT, left reaction time; RRT, right reaction time.

(Fig. 4b). These results suggest thus that the calibration of sensory-motor transformations induced by prism adaptation, which directly affects visual space representation and action, may also alter the orientation of attention in other sensory modalities (Courtois-Jacquin et al., 2001).

Moreover intentional disturbance showed by neglect patients may be also improved after prism adaptation. These disturbances may be illustrated by the fact that preparation of a movement sequence ending to the left is longer than a movement sequence ending to the right in neglect patients (Rode et al., 2000). In two neglect patients we tested the effect of a prism adaptation period on this parameter and showed that the initial increase in reaction time for movements ending to the left was reversed after the adaptation (Table 2), suggesting that prism adaptation can produce an effect on higher-level control of action which are linked to intention to act to the right or to the left (Rossetti and Pisella, 2002).

However, further investigations are required to confirm whether prism adaptation mechanisms alter the brain mechanisms for the spatial distribution of attention or intention, as there is no suggestion of such a link in the classical prism adaptation literature.

Prism adaptation and neural structures involved

An intriguing question is to know whether prism adaptation favors the spontaneous recovery of neglect or facilitates the occurrence of selective compensation mechanisms. This question refers either to the cerebral plasticity naturally involved after the
Fig. 5 (continued). (b) Writing. Writing under dictation and free drawing from memory (daisy) prior to prism exposure (pre-test), and after a delay of about 1 h (post-test) and 48 h (late-test) in a neglect patient (R.R.O.) with neglect dysgraphia. Before adaptation, writing showed a neglect of the left part of the sheet, a rightward shift of beginning of line and oblique slope of lines. These abnormalities are reduced after prism adaptation. The patient used the entirety of sheet space, the lines are horizontal and the legibility of text was improved.
Fig. 5 (continued). (c) Postural instability. Comparison of effects of prism adaptation period shifting the visual field to the right or the left and neutral prisms in three groups of five right-brain-damaged patients on postural imbalance assessed by a statokinesimetric platform. The figure indicates that only an adaptation to rightward-shifting prisms reduces significantly the displacement of the center of pressure. (From Tilikete et al., 2001.)

cerebral damage or to the cerebral plasticity specifically activated by the visuo-motor adaptation task. In normal subjects, neural structures considered to be involved in prism adaptation have long been restricted to the cerebellar region (Jeannerod and Rossetti, 1993), as shown by the inability of adaptation of patients with focal olivocerebellar lesion (Weiner et al., 1983; Martin et al., 1996). The posterior parietal cortex contralateral to the acting hand might be activated during adaptation to a prism-induced shift of the visual field (Clower et al., 1996). The reciprocal connections between the deep cerebellar structures and the posterior parietal cortex provide an anatomical substrate that may support the cerebellar participation also in high-order processing (Schmahmann, 1998; Rossetti et al., 2000). Lastly, one may also suppose that the motor component of the visuo-motor adaptation task (pointing movements of the ipsilesional hand) may also favor the implication of the ipsi- and contralateral frontal areas in recovery of neglect following prism exposure. Imagery studies show that these areas are involved in natural recovery of neglect. The reciprocal connections between the cerebellum support of motor control and adaptation and the frontal lobe support of action and intention may be activated following prism adaptation (Rode et al., 2001b).

Duration of improvement

One of the side effects of questions about basic mechanisms is that they should help us to answer the intriguing question of why the effects of prism adaptation last for so long in the patients, whereas the after-effects observed in normals in the same conditions resolve within a few minutes (see Table 1).

The main interest of prism adaptation is that the effects produced by a single 5-min session of adaptation last for much longer than any other method. Two group studies showed fully sustained effects after at least 2 h (Rossetti et al., 1998a,b), and 1 day (Farnè et al., 2002), respectively. Case studies reported even more prolonged improvements, lasting for about 4 days (Jacquin et al., 1998; Pisella et al., 2002). Although a recent group study found no sustained improvement of neglect one week after the adaptation session (Farnè et al., 2002), it is possible that some patients are improved for a longer period than others (McIntosh et al., 2001).

But the best prospect for rehabilitation purposes is to repeat adaptation sessions. Recently a treatment with prismatic lenses in twice-daily sessions over a period of 2 weeks was applied in a group of seven neglect patients compared with a control group. The results showed an improvement in the experimental patient’s performance after prism adaptation, which was maintained during a 5-week period after treat-
Fig. 6. Effect of prism adaptation on resistant hemispatial neglect. Copy drawing was explored 5 years after the stroke in a case of persistent hemispatial neglect. The patient was a 72-year-old, right-handed female who suffered from a severe left hemiplegia with left hemi-anesthesia, hemianopia and neglect following a large hematoma of the right cerebral hemisphere. The patient had benefited from specific active training for neglect and caloric vestibular stimulation during the first year post-stroke. Before prism exposure (pre-test), she copied only the most rightward parts of the drawing, showing an associated object-centered neglect. In the immediate post-test, two items were added to the patient’s drawing; in the late-test (after 2 h), all items are drawn, the object-centered neglect was reduced (limited to the bee-hive) and the constructive apraxia had also improved.

This long-term improvement of neglect symptoms was found in standard as well as in behavioral tests and in all spatial domains (Frassinetti et al., 2002). We have investigated the effects of a daily session of adaptation and found no further improvement in the days following the initial exposure to prisms. Controlled clinical trial has to be initiated with a longer between-sessions period. In addition, the functional outcome for the patients will need to be investigated carefully. So far only a few measures have been provided (e.g. wheelchair driving, writing or postural control) (Fig. 5a–c).

Another of the crucial questions raised by the observation of a strong and sustained improvement of hemispatial neglect by a single short adaptation session is whether this plastic effect is restricted
to the acute phase of the deficit. In our original study patients were tested between 3 weeks and 14 months post-stroke (Rossetti et al., 1998a). We have now collected data on a group of patients who were exposed to the adaptation procedure between 5 and 12 years post-stroke and surprisingly found the same amount of improvement. Fig. 6 shows the example of a patient who benefited from prism adaptation 5 years after her stroke.

Neglect-like syndrome after prism adaptation in healthy subjects

One of the most striking aspects of prism exposure in neglect patients is that, in strong contrast to healthy subjects, they exhibit a reduced awareness of the optical effects of the prisms. Most patients performed accurate pointing movements with the prisms on, which implies that their initially misdirected pointing trajectories are corrected during the course of the movement. Nevertheless they do not report that the goggles are responsible for any visual shift, even when specifically questioned. In a way, they show a kind of ‘hypernosognosia’, as if they had been so used to missing things on the left side that they over-attribute the prism-induced errors to themselves. This hypothesis would also explain why they develop more adaptation than healthy individuals in identical prism exposure conditions.

Conclusion

Taken as a whole, investigations of the effects of prism adaptation on hemispatial neglect have been very frustrating in terms of the difficulty in providing plausible theoretical accounts for the strong positive effects produced. These effects can by no means be compared with the classical knowledge about prism adaptation in healthy individuals, for whom both the duration and the generalization of the adaptation after-effects are extremely restricted. However, two interesting perspectives have emerged from these studies. The theoretical perspective is that it seems possible to emulate hemispatial neglect in healthy individuals (Colent et al., 2000; Michel et al., 2002; N. Berberovic and J.B. Mattingley, pers. commun., 2002). The practical perspective is that the long duration of the improvement produced by prism adaptation should give rise to clinical studies proposing routine protocols for the rehabilitation of patients.

Acknowledgements

This work was supported by INSERM (PROGRES) and ACI Plasticité. The authors wish to thank Jean-Louis Borach for his technical assistance.

References


