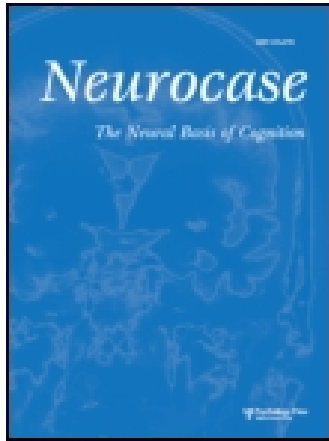


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# Prism Adaptation Changes Perceptual Awareness for Chimeric Visual Objects but Not for Chimeric Faces in Spatial Neglect after Right-hemisphere Stroke

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Prism adaptation can ameliorate some symptoms of left spatial neglect after right-hemisphere stroke. The mechanisms behind this remain unclear. Prism therapy may increase exploration towards the contralesional side, yet *without* improving perceptual awareness, as apparently for the left side of chimeric face stimuli (Ferber *et al.* 2003). However, other prism studies suggest that perceptual awareness might be improved (e.g., Maravita *et al.*, 2003). We tested the impact of prism therapy on visual awareness for the left side of chimeric objects as well as chimeric faces, in three neglect patients. Prism therapy dramatically improved awareness for the identity of the left side of chimeric non-face objects, but had no effect on judging expressions for chimeric faces. The latter may thus be unique in showing no prism benefit.

## Introduction

Spatial neglect is a common and disabling syndrome after stroke that poses a significant challenge for rehabilitation. Many right-hemisphere stroke patients may exhibit neglect acutely, up to 80% in some reports (e.g., Stone *et al.*, 1993). Moreover, up to 30% of such right-hemisphere cases may still show persisting symptoms of neglect after three months (e.g., Cassidy *et al.*, 1998). Spatial neglect is a multi-component syndrome (e.g., see Vallar, 1998), with the deficits including losses of awareness and of exploration towards the contralesional side of space, even when primary sensory and motor functions are intact. Neglect patients may fail to acknowledge the existence of contralesional stimuli, and may even neglect contralesional parts of their own body or of mental representations (Heilman *et al.*, 1997; Vallar, 1998; Mesulam, 1999; Karnath *et al.*, 2002; Buxbaum *et al.*, 2004; Driver *et al.*, 2004). When exploring a scene, their eye, head, body and hand movements may also fail to be directed towards leftward elements (Hornak, 1992; Karnath *et al.*, 1998; Farne *et al.*, 2003; Marotta *et al.*, 2003; Fruhmann-Berger and Karnath, 2005). Neglect is a debilitating condition in everyday life and has been identified as a negative prognostic

factor for functional outcome after stroke (e.g., Kinsella and Ford, 1985; Buxbaum *et al.*, 2004; Gillen *et al.*, 2005).

Efforts to rehabilitate neglect have led to a variety of approaches over the last two decades, including caloric vestibular stimulation; transcutaneous mechanical or electrical stimulation; proprioceptive stimulation; and attention retraining (for a review see Rossetti and Rode, 2002; see also Vallar, 1998). Most such methods typically either produce effects that dissipate quickly; or require many hours of therapy; or beneficial effects may not generalize outside the training context (e.g., Rubens, 1985; Vallar *et al.*, 1993; Karnath, 1994, 1995; Antonucci *et al.*, 1995; Vallar *et al.*, 1995; Wiart *et al.*, 1997; Pierce and Buxbaum, 2002; Rossetti and Rode, 2002; Kerkhoff, 2003). But one new and promising rehabilitative approach to neglect may surmount these shortcomings, namely adaptation to rightward optical displacements induced by *prisms* (Rossetti *et al.*, 1998; Farne *et al.*, 2002; Frassinetti *et al.*, 2002; Rossetti and Rode, 2002; Maravita *et al.*, 2003; Redding and Wallace, 2005).

Prism-adaptation therapy has been identified as a potential new 'cure' for neglect (Mattingley, 2002). While this intervention can be relatively brief and non-invasive (comprising just a few minutes of pointing to visual targets while wearing rightward-deviating prisms that induce leftward pointing corrections), it has been reported to produce relatively long-lasting improvements, that may generalize across different aspects of neglect, in several independent studies to date (see Rossetti *et al.*, 1999; Tilikete *et al.*, 2001; Farne *et al.*, 2002; McIntosh *et al.*, 2002; Pisella *et al.*, 2002; Rossetti *et al.*, 2004; Maravita *et al.*, 2003; Angeli *et al.*, 2004a; Berberovic *et al.*, 2004; Dijkerman, *et al.*, 2004).

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Using a short adaptation period to a prismatic optical shift of 10° to the right, Rossetti *et al.* (1998) were the first to demonstrate that spatial neglect may be significantly improved by such prism adaptation, as measured on several traditional paper-and-pencil clinical tests for neglect (line cancellation, line bisection, copying of figures). Surprisingly, a very brief adaptation procedure (lasting only 2 to 5 minutes before the prisms were removed) produced improvements that were apparently sustained for at least two hours. Subsequent studies have reported even longer-lasting benefits (e.g., Frassinetti *et al.*, 2002; McIntosh *et al.*, 2002; Pisella *et al.*, 2002).

Adaptation to rightward optical prismatic shifts has now been reported to improve numerous aspects of left neglect, including postural control (Tilikete *et al.*, 2001) and other activities relevant to everyday life, such as wheelchair navigation (Rossetti *et al.*, 1999). Moreover, its beneficial effects may generalize beyond the visuo-motor domain, to include haptic exploration (McIntosh *et al.*, 2002) and tactile extinction (Maravita *et al.*, 2003), as well as tasks requiring a verbal rather than a motor response (Farne *et al.*, 2002). Finally, prism adaptation has been shown to impact on more abstract levels of spatial representation also, including mental imagery, on tasks such as drawing from memory or reporting cities from a mental map (Rode *et al.*, 2001), and number-line bisection (Rossetti *et al.*, 2004).

But despite these many apparently positive effects, the mechanisms underlying the impact of prism therapy upon spatial neglect remain unclear (see Farne *et al.*, 2002; Mattingley, 2002; McIntosh *et al.*, 2002; Pisella *et al.*, 2002; Dijkerman *et al.*, 2003; Rode *et al.*, 2003; Angeli *et al.*, 2004b; Redding and Wallace, 2005; for discussions). In one challenging study, Ferber, Danckert, Joanisse, Goltz and Goodale (2003) suggested that prism therapy may affect only spatial exploration (apparently in keeping with the visuo-motor nature of the prism intervention), but have no effect on deficient perceptual awareness *per se*, nor on the underlying mechanisms of neglect. Ferber *et al.* tested a single neglect patient with chimeric faces, as previously used (Mattingley *et al.*, 1993, 1994) to test some aspects of visual awareness in neglect. As in Mattingley *et al.* (1993, 1994), the patient was shown pairs of chimeric face stimuli (i.e., stimuli that can join together different left and right halves of faces), one above and one below, and asked which depiction of the same person looked happier. Right-hemisphere patients with left neglect typically select the face that is smiling on its right side; whereas the opposite tends to be the case for normal controls.

The critical new result in Ferber *et al.* (2003) was that prism adaptation (to a 10° rightward optical shift, analogous to the Rossetti *et al.* 1998 procedure) did *not* improve sensitivity to the expression on the neglected left side of the chimeric faces; even though it *did* improve ocular exploration of that side by their patient. Moreover, Ferber *et al.* reported that their patient never became aware of the chimeric nature of the stimuli used. They therefore argued that while prism therapy can beneficially affect exploration in neglect (as indicated by their saccadic data), it may have no effect on perceptual

awareness *per se* (as indicated by the null effect on emotional-expression judgements for the chimeric faces, and apparently on awareness of the chimeric nature of these stimuli also, in their single case). They concluded that prism therapy “fails to influence the underlying mechanisms of neglect” (p. 1826). It should also be noted that in an earlier study, Vallar *et al.* (1994) had reported that while vestibular stimulation can benefit other aspects of neglect (e.g., in cancellation measures), it apparently did not benefit awareness of chimeric-like figures in their patients.

While Ferber *et al.*'s (2003) results are striking, other findings argue that prism therapy may affect perceptual awareness in at least some patients, on some tasks. Maravita *et al.* (2003) observed that prism therapy could ameliorate tactile extinction in each of the four patients they tested, in a non-explorative task that required only verbal reports of somatosensory perceptual awareness. Moreover, as noted above, prism therapy can apparently affect awareness in several other aspects of neglect also (e.g., in imagery tasks). The apparent discrepancy with the Ferber *et al.* (2003) result still requires explanation; but for the existing results it is hard to compare directly across different studies that applied very different methods (sometimes in different sensory modalities) to separate patients. One possibility is that face-processing, as indexed in the Ferber *et al.* chimeric study with the Mattingley *et al.* (1993) task, may be a special case. This might conceivably accord with abundant evidence for specific neural mechanisms for the processing of faces (e.g., see Rumiaty *et al.*, 1994; Farah, 1995; Farah *et al.*, 1995a; Farah *et al.*, 1995b; Nachson, 1995; Kanwisher, 2000; Grill-Spector *et al.*, 2004; Yovel and Kanwisher, 2004), and of emotional facial expressions (e.g., Adolphs *et al.*, 1995; Dolan *et al.*, 1996; Morris *et al.*, 1996, 1998; Phillips *et al.*, 1998; Blair *et al.*, 1999; Kesler-West *et al.*, 2001; Posamentier and Abdi, 2003; Vuilleumier *et al.*, 2003; Winston *et al.*, 2003).

Accordingly, here we examined the impact of prism therapy on awareness in two chimeric tasks, applying both tasks to all three of the neglect patients studied. One task used emotional-expression judgements for chimeric faces (just as in Ferber *et al.* 2003, albeit now without oculomotor measurements, which were not possible here due to clinical and technical constraints). For comparison, the other task we implemented here used chimeric non-face objects instead of faces. Chimeric objects have often been used to assess visual neglect (e.g., Seron *et al.*, 1989; Young *et al.*, 1992; Buxbaum and Coslett, 1994; Vallar *et al.*, 1994; Walker and Young, 1996; di Pellegrino *et al.*, 1995; Peru *et al.*, 1997), but should presumably not involve any face-specific mechanisms. The novel aspect here was thus to examine any influence of prism therapy for both chimeric faces *and* chimeric objects. If the findings of Ferber *et al.* (2003) generalize to our patients, we should find no benefit of prism therapy for the chimeric faces. If prism therapy does not affect visual awareness, the same should apply for chimeric objects. Alternatively, if there is something special about chimeric faces,

we might find a prism benefit for the chimeric objects here but not for the chimeric faces.

## Method

### Patients

Three consecutive right-hemisphere stroke patients with left neglect were recruited (for a brief summary of clinical details, see Table 1). All showed neglect on some clinical paper-and-pencil measures, including cancellation, line bisection, figure copying and drawing from memory, as described below. Diagnosis of left visual neglect was based on the presence of at least 30% omissions on the left side of the page for the cancellation tests; a minimum rightward deviation of 12% or more in the line bisection task; and omission of left-sided elements in the two drawing tests. Please note that in the present study design, each patient served as their own control (i.e., before versus after prism therapy).

Patient EY was a 74-year-old female, admitted to hospital with left-sided weakness and confusion. A CT scan 5 days later showed an area of low attenuation within the R parieto-occipital lobes consistent with an infarct (see Figure 1A). EY was tested experimentally at 3 months post stroke, and still showed clear signs of neglect on paper and pencil testing, cancelling only 9/27 stars on the left but 20/27 on the right for the Star Cancellation test from the Behavioural Inattention Inventory (Halligan *et al.*, 1990). She also showed signs of neglect in line bisection (for five 21cm lines, her mean error to the right was 4.21cm,  $sd = 3.32$ ). She also showed neglect on the BIT figure copying subtest and on drawing from memory. She had complete left homonymous hemianopia but showed visual extinction within her good visual field on confrontation, systematically extinguishing the leftmost out of two stimuli (wiggled fingers) when these were presented simultaneously within her right visual field (while fixating the examiner's nose); but accurately detecting a

single stimulus when presented at either position within this intact field.

Patient AK was a 64-year-old male who suffered a haemorrhagic stroke. He was found collapsed by a relative, showing slurred speech, confusion and inability to move. CT on admission showed a subcortical intracranial haemorrhage, involving deep white matter in the region of the right external capsule and claustrum, leaving insular cortex intact (see Figure 1B). AK was tested experimentally four and a half months post stroke, when he still showed contralesional neglect on several paper and pencil tests. On the Stars cancellation test he cancelled 12/27 stars on the left side but 24/27 on the right side. On the Mesulam shape cancellation test (Weintraub and Mesulam, 1985) he cancelled only 4/30 targets on the left but 21/30 on the right. Some signs of neglect were also found in line bisection (for five 21cm lines, his mean error to the right was 1.39cm,  $sd = 0.75$ ). AK also presented with complete left homonymous hemianopia, but also showed visual extinction within his good visual field on confrontation, as described above; plus left-sided motor weakness for the upper and lower limb. He also exhibited some mild dysarthria and dysphasia, but this did not affect our experimental testing.

The third patient, CO, was a 57-year-old female, who suffered a large infarct in the territory of the right middle cerebral artery. CT performed one day after onset of her symptoms revealed an area of low attenuation involving the white matter and overlying cortex in the right frontal lobe, right basal ganglia and right insular cortex (see Figure 1C). She was admitted to hospital after waking up with left-sided weakness. She was fully oriented in time, place and person. CO was tested experimentally 3 weeks post stroke. At this time, she still showed neglect on clinical paper and pencil tests, cancelling only 5/27 targets on the left but 24/27 on the right in the Star cancellation test. She also showed some neglect on a line bisection task (for five 21cm lines, her mean error to the right was 2.4cm,  $sd = 1.36$ ). CO had fully intact fields on confrontation, but showed visual and tactile extinction

**Table 1.** Summary of individual patient details

Patient	Sex	Age	Hemianopia	Post-injury <sup>1</sup>	Line bisection <sup>2</sup>	Star cancellation	Lesion site and pathology
AK	M	64	Yes	13	13.2	L: 12/27 R: 24/27	Right haemorrhage involving the deep white matter in the region of the external capsule, claustrum and extreme capsule.
CO	F	57	No	20	22.8	L: 5/27 R: 24/27	Right MCA infarct, involving the white matter and overlying cortex in the right frontal lobe, right basal ganglia and right insular cortex.
EY	F	74	Yes	3	40	L: 9/27 R: 20/27	Right parieto-occipital infarct (PCA/MCA 'watershed').

Note. <sup>1</sup>Time post-injury in weeks, <sup>2</sup>Percentage of deviation towards the right.

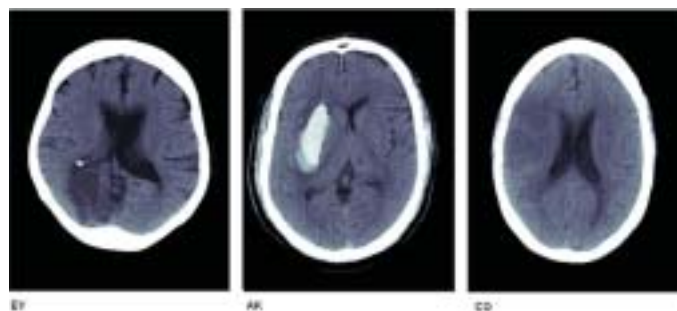


Fig. 1. CT scans of EY, AK and CO.

to confrontation, as well as left-sided motor weakness for the upper and lower limb.

These three patients thus all had fairly typical lesions and symptoms for right-hemisphere stroke patients with left neglect.

### Stimuli

The stimuli for the chimeric object task consisted of 23 chimerics (i.e., the left half of one object joined to the right half of another; see Figure 2A for some examples). These chimerics were generated from 46 common objects and animals, selected from the Snodgrass and Vanderwart (1980) collection. The figures were cut along the vertical meridian into left and right halves and then recombined in order to produce the 23 chimeric objects. Mirror-reversed versions of these chimerics were also used (to ensure equivalent stimulation and object identities on each side overall, across the experiment). Thus each patient saw each particular chimeric combination of two objects twice, but only once for a particular left-right arrangement. Forty-six object displays were generated in total. The figures ranged in size from  $19 \times 11$  cm to  $12 \times 11$  cm (thus subtending viewing angles of  $\sim 21^\circ \times 12^\circ$  degrees max, at the viewing distance of approximately 50 cm), and were printed individually at the centre of white A4 sheets of paper.

For the chimeric faces, 20 pairs of chimeric faces were used, taken and adapted from Mattingley, Bradshaw, Phillips and Bradshaw (1993); see Figure 2B for examples. These chimeric faces were generated from 10 pictures of 10 different people with a neutral expression, plus 10 pictures of those same people smiling. The photographed faces were divided along the vertical midline, and left and right halves from different photographs of the same person were then juxtaposed in such a way that a smiling half face was on the left and a neutral half face on the right; or vice versa in mirror-image displays. Chimeric face stimuli were then arranged in vertical pairs, one above the other, so that each pair contained two chimeras of the same person, one neutral in the left half and smiling in the right half, and the other the reverse of this, with vertical position counterbalanced, just as in Mattingley *et al.* (1993) and Ferber *et al.* (2003). Thus, the two stimuli arranged vertically were left/right mirror images of each

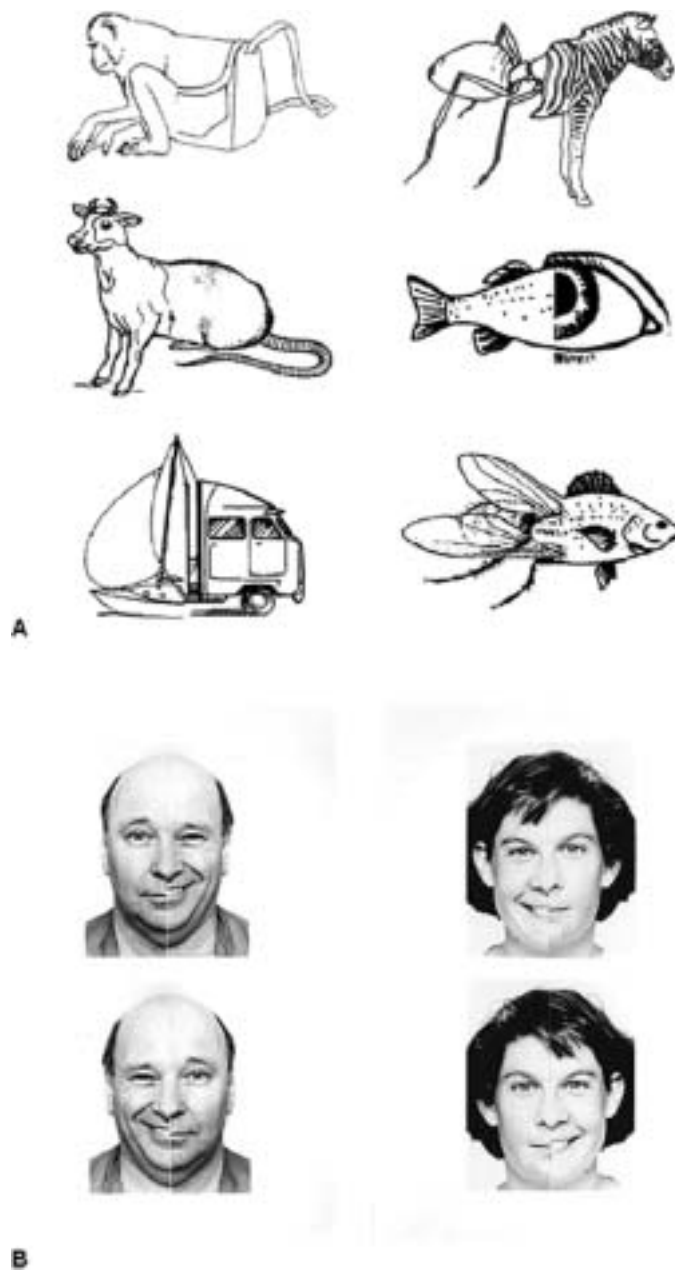


Fig. 2. Examples of A) chimeric object; and B) chimeric face stimuli used.

other, see Figure 2B. Each chimeric face subtended approximately  $6^\circ \times 8^\circ$  degrees.

### Procedure

Patients were given the two chimeric tasks (i.e., faces and objects) both before and after the prism adaptation procedure. For the object task, they were shown the 46 chimeric objects and were asked to report what these contained (as in previous studies of neglect with chimeric objects, e.g., Seron *et al.*, 1989; Young *et al.*, 1992; Buxbaum and Coslett, 1994; Vallar *et al.*, 1994; di Pellegrino *et al.*, 1995; Walker and Young,

1996; Peru *et al.*, 1997). Specifically, the patients were told that they would be shown a series of line drawings and they simply had to “report what they saw” in each drawing. In the face task, patients were told that they would be shown a series of faces in pairs and that they had to choose the one they thought “looked happier”. They were then shown the 20 pairs of chimeric faces and asked to indicate verbally whether the upper or lower member of each pair looked happier, just as in Mattingley *et al.* (1993) and Ferber *et al.* (2003). The order of stimuli presentation was randomized both before and after the prism adaptation procedure, for both tasks and for all patients, but face or object task was blocked. The order of this task presentation (i.e., objects or faces first) alternated between patients, with only patient EY doing the face task first, and was held constant before and after prism adaptation for each patient. The stimuli were placed in front of the patients, on a table, centered on the midsagittal plane of their head and trunk and remained in view until the patients gave a response, without any time limit.

For the prism-adaptation procedure the patients also sat at a table. During adaptation they wore base-left wedge prisms that induced a 10 degree optical shift to the right. The adaptation to prisms was accomplished by having the patients perform 60 repeated pointings with their right hand to two targets placed on a table, 10 degrees to the left or right of the center of their midsagittal plane, at a distance of ~55 cm from their trunk, in a randomly intermingled sequence. Patients were instructed to make fast movements to the targets and then return their arm to the initial starting position on the table by their trunk center. The initial position of their arm was occluded by a horizontal occluding board, occluding approximately 25% of the distance between the patient and the targets. Hence patients could see their arm only while moving it towards their target, but had closed-loop visual feedback for any terminal errors, thus inducing corrections and adaptation to the prismatic deviation. Total exposure to the prisms was approximately 10 minutes for each patient, and the prisms were then removed prior to retesting of the object and face chimerics.

To obtain a measure of open-loop pointing for assessing prism adaptation, patients were asked to point several times to a single target (a red dot) placed at the center of their midsagittal plane at a distance of 55 cm, with their right hand, both before and after the prism adaptation procedure. Vision of the hand was obscured throughout this aspect of the procedure. Each patient made 5 open-loop pointings before the adaptation procedure, plus 5 immediately after removing the prisms, to assess whether exposure to rightward shifting prisms had induced the expected (leftward) prism after-effect on open-loop pointing.

## Results

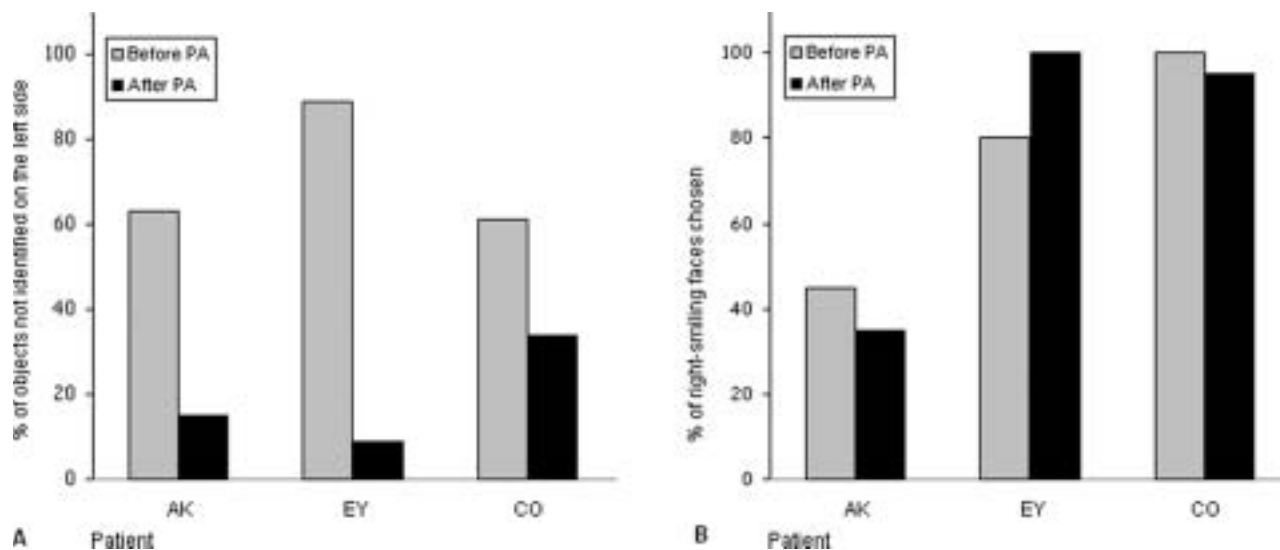
All three patients showed the expected leftward shift in their open-loop pointing after exposure to the prisms (i.e., a prism after-effect), indicating that the adaptation procedure was successful. EY’s pointing after the adaptation procedure

showed a mean leftward deviation of 4.6° degrees (sd 0.58°); CO showed 4.4° degrees of this (sd 0.33°); and AK 2.7° degrees (sd 0.88°). These *leftward* deviations in open-loop pointing away from the physically central target, after the adaptation procedure, were significantly different from the slight tendency for rightward deviation observed before the prismatic procedure, for all patients (EY had shown  $-0.11^\circ$  pointing deviation before-prisms (sd 0.77°),  $t(4) = -7.418$ ,  $p = 0.002$ , in comparison to the post-prism measure; AK  $-0.57^\circ$  (sd 0.82°),  $t(4) = -6.325$ ,  $p = 0.003$ ; CO  $-0.69^\circ$  (sd 0.44°),  $t(4) = -20.140$ ,  $p = 0.000$ ). Thus all patients showed significantly more leftward deviation in open-loop central pointing after exposure to the rightward deviating prisms, as expected due to prism adaptation.

Turning to the chimeric objects, data were excluded from any chimeric objects for which the patient failed to name either side correctly (this excluded just two stimuli for the cases of EY and of CO, but none for patient AK). Before prism adaptation, all patients showed significant neglect for the left side of the chimeric objects. Specifically, AK was able to identify the left side of only 17/46 chimeric objects, thus neglecting 63% of the left sides of the object stimuli presented to him; EY correctly identified only 3/44 left sides of the chimeric objects, thus neglecting 89.1% of the left sides; and CO only 17/44, thus neglecting 61% of the left sides. By contrast, these patients successfully identified the right side of almost all stimuli (i.e., except for the 2/46 stimuli for EY and for CO mentioned above, where neither side was named).

These before-prism data simply confirm the presence of strong left neglect for chimeric objects in all three patients. The critical new results were obtained after prism adaptation. This dramatically *reduced* the lack of awareness for the left side of chimeric objects. After prism adaptation, AK now correctly identified 39/46 of the left sides, thus neglecting only 15.2% (as compared with 63% neglected prior to prism exposure); EY now correctly identified 40/44, thus neglecting only 9.1% of the chimeric objects’ left sides (as compared with 89.1% previously); and CO correctly identified 29/44, thus neglecting 34% of the left sides (as compared with 61% previously); see Figure 3A. For all three patients individually, this dramatic improvement in the number of left sides of chimeric objects named correctly after versus before prism adaptation was significant ( $\chi^2(1) = 22.1$ ,  $p < 0.0001$  for AK,  $\chi^2(1) = 40.9$ ,  $p < 0.0001$  for EY and  $\chi^2(1) = 5.5$ ,  $p < 0.018$  for CO). Performance for right sides remained fully intact after prism exposure.

This dramatic impact of the prism intervention on awareness for the left side of chimeric objects contrasted with the findings for chimeric faces, which found absolutely no impact of prism adaptation, in accord with Ferber *et al.*’s (2003) previous single-case study. Before prism-adaptation, choices of the face with a smiling right half as the ‘happiest’ were 9/20 (45%) for AK; 16/20 (80%) for EY, and 20/20 (100%) for CO. The corresponding figures after prism adaptation were 7/20 (35%), 20/20 (100%) and 19/20 (95%) respectively, leading to no significant differences ( $p = .7$  for



**Fig. 3.** A) Percentage of chimeric objects not identified on the left side, and B) Percentage of chimeric faces with right-half smiling judged as 'happier', for each individual patient, before (light bars) and after (dark bars) prism adaptation (PA). Note the dramatic improvements for each patient following prism adaptation in A but not B.

AK,  $p > .1$  for EY, with any trend in the 'wrong' direction; and  $p = .9$  for CO); see Figure 3B.

Thus, for the chimeric faces, patients EY and CO both showed strong left neglect, manifested as expression judgements being pathologically based mainly on just the right side of the face, unlike the normal tendency for the left side of the face to predominate (cf. Levy *et al.* 1983; Levine and Levy, 1986; Mattingley *et al.*, 1993, 1994). Indeed these two patients fell well outside the normative range for this particular chimeric task (see Mattingley *et al.*, 1994); only patient AK did not. However, the main point for present purposes is that, in striking contrast to the present data from chimeric objects, our patients' performance for chimeric faces in the expression task was completely *unaffected* by prism adaptation, whereas this significantly reduced left neglect for the chimeric non-face objects (see Figures 3A and 3B).

## Discussion

Our new results indicate that adaptation to right-shifting prisms can substantially improve visual awareness for the contralesional side of chimeric visual objects, in patients with left neglect after right-hemisphere damage. However, in accord with Ferber *et al.* (2003), they also indicate that such a beneficial influence is *not* found for expression judgements on chimeric faces, as in their single-case study also. Here a benefit from prism therapy was found only for identification of chimeric non-face objects, which was the critical new additional measure introduced, not for the chimeric face task. The latter aspect of our results thus accords empirically with Ferber *et al.*'s (2003) findings, but here we extend those to show that a very different result is found with chimeric

non-face objects. The new results for chimeric objects show unequivocally that prism adaptation can in fact improve some aspects of deficient visual awareness in neglect patients, which may thus extend its rehabilitative potential.

Having established the dramatic difference in the impact of prism therapy on chimeric objects versus faces, we can now turn to consider possible reasons for this. This could be due to the nature of the stimuli, and of associated neural mechanisms for processing faces versus other classes of objects (see Rumiati *et al.*, 1994; Farah, 1995; Farah *et al.*, 1995a; Farah *et al.*, 1995b; Nachson, 1995; Kanwisher, 2000; Grill-Spector *et al.*, 2004; Yovel and Kanwisher, 2004); or conceivably to the nature of the specific tasks imposed here for faces versus objects; or to a combination of these factors. These possibilities could in principle be tested by further variations on the paradigms used here, but this was not possible with the present patients due to clinical constraints.

For normal observers, two halves from the same or similar face may 'fuse' together perceptually, possibly more so than for other classes of chimeric stimuli (e.g., see Young *et al.*, 1987), perhaps because the two sides are more similar with typical faces, but it should be noted that patients EY and CO clearly did not base their expression judgements upon the combined or fused sides of the chimeric faces here, being influenced primarily by just the right side. It might be argued that neglect with chimeric faces is simply stronger than that for chimeric objects (perhaps because the difference between sides is less obvious), and hence is harder to ameliorate. However, patient AK showed less tendency for neglect than EY and CO with the faces, yet still showed absolutely no prismatic improvement on these. Thus, the differential impact of prism therapy upon chimeric objects but not upon chimeric faces here seemed to

apply regardless of the absolute level of neglect on either task. This difference may relate to the existence of specialized face-processing mechanisms in the brain that may be less influenced by the prism intervention than for other classes of stimuli. Alternatively, it might reflect the difference between sides being less obvious for typical chimeric face than typical chimeric object stimuli and also relate to the fact that the chimeric face stimuli carry less visual information about the fact that they are chimeric, as compared to the chimeric objects. While it might be methodologically challenging to equate exactly the extent of visual difference between left/right halves for chimeric faces versus objects, it should be possible to vary the size of such differences parametrically within each stimulus type in future work, to determine the impact of this particular stimulus factor.

A further possibility concerns the different tasks that were used with face chimerics versus object chimerics here. We used two of the standard, established measures of neglect with chimeric stimuli, namely, judgement of emotional expressions for chimeric faces (cf. Mattingley *et al.*, 1993, 1994; Ferber *et al.*, 2003), and naming of chimeric objects (cf. Seron *et al.*, 1989; Young *et al.*, 1992; Buxbaum and Coslett, 1994; di Pellegrino *et al.*, 1995; Walker and Young, 1996; Vallar *et al.*, 1994; Peru *et al.*, 1997). It is possible that identification/naming may be more influenced by neural structures that are sensitive to prism adaptation (and any effects that this might have upon spatial attention, etc); whereas emotional judgements of faces might instead be based upon distinct neural structures, as suggested by some other lines of evidence (Dolan *et al.*, 1996; Morris *et al.*, 1996; Morris *et al.*, 1998; Phillips *et al.*, 1998; Blair *et al.*, 1999; Vuilleumier *et al.*, 2003; Winston *et al.*, 2003). Such expression-related pathways may be uninfluenced by prisms, representing parts of the 'emotional' brain instead. A related possibility is that prism therapy had a differential effect on the object versus the face task due to the former requiring explicit naming, but the latter potentially being a more 'implicit' task. One way to test these possibilities in the future might be to require non-emotional identification judgements for chimeric faces, using stimuli that show different face identities on the two sides; but this was beyond the scope of the present study. With such new stimuli, one might also compare identification versus emotional expression tasks for the very same chimeric face stimuli, and thereby equate stimulus factors when comparing tasks.

While further research with such variations on the paradigms introduced here may shed light on these remaining issues, the present results already clearly indicate that prism therapy can improve perceptual awareness for the contralateral side of objects in neglect patients, even though it has no impact on expression-judgements for chimeric faces. The latter observation replicates Ferber *et al.*'s (2003) single-case finding in three further cases; but the positive new finding with non-face stimuli indicates that, for objects at least, perceptual awareness can in fact be substantially improved with prism interventions in spatial neglect.

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