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CME

Prism adaptation can improve contralesional tactile perception in neglect

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Abstract—The authors show that prismatic adaptation can reduce tactile inattention in stroke patients with unilateral neglect. Four patients with visuospatial neglect and tactile extinction underwent 10-minute application of 20° right-shifting prismatic lenses during pointing. This improved contralesional tactile perception in all patients, even for a task requiring no exploration or spatial motor responses. This finding suggests a potential role for prismatic adaptation in the rehabilitation of multiple sensory modalities in patients with neglect.

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Unilateral neglect is common after right hemisphere lesions. Neglect patients ignore stimuli on the contralesional (usually left) side of space and body.¹ Some patients may show extinction, whereby single stimuli can be perceived on each side, but contralesional stimuli go undetected during bilateral stimulation.² Rehabilitation of visuospatial neglect has proved challenging, but recent work suggests striking effects from prism adaptation (PA).³ Prismatic lenses induce an optical deviation toward the ipsilesional side for several minutes, while patients perform pointing movements with the ipsilesional hand toward visual targets. To correct for the visual shift induced by the lenses, patients must make motor corrections toward the contralesional side during each pointing movement. At the same time, they receive visual feedback on any inaccuracy further to the ipsilesional side than usual. Once prisms are removed, patients show a directional pointing error toward the contralesional side (prism aftereffect).³ This aftereffect can be particularly long-lasting for neglect patients^{3–6} as compared with PA in subjects, and critically is accompanied by improvements in visuospatial neglect lasting several hours or days.⁵

Prism adaptation has been shown to improve several visuospatial neglect symptoms, including visual search or drawing,³ neglect dyslexia,⁴ personal neglect, and haptic⁷ and visuomotor tasks.⁵ However, it remains unknown whether the beneficial effect of PA can directly affect perception in neglect patients or rather modulates primarily active exploration strategies (which may even affect visual imagery).⁶ It also remains unknown whether PA can modulate the somatosensory deficits associated with neglect.⁸ To address these issues, we tested whether PA can ameliorate tactile extinction.

Methods. Four patients with right hemisphere damage (figure) and tactile extinction were studied after giving written consent. The Ethics Committee of the Homerton Hospital in London (UK) previously approved the study. All patients showed some degree of neglect on standard tests (table 1). Tactile perception was assessed experimentally using electromagnetic solenoids (Trans Dimension, USA) to deliver single unseen 100-ms taps on the index finger pad of either hand. Patients placed their hands in their lap while fixating a cross centered on a monitor in front of them. Tactile stimuli could be delivered unilaterally to either the right or left hand (18 per side for Patients 2 and 4, 12 for Patients 1 and 3) or to both hands simultaneously (18 for Patients 2 and 4, 24 for Patients 1 and 3) in an intermingled sequence. Six “catch” trials

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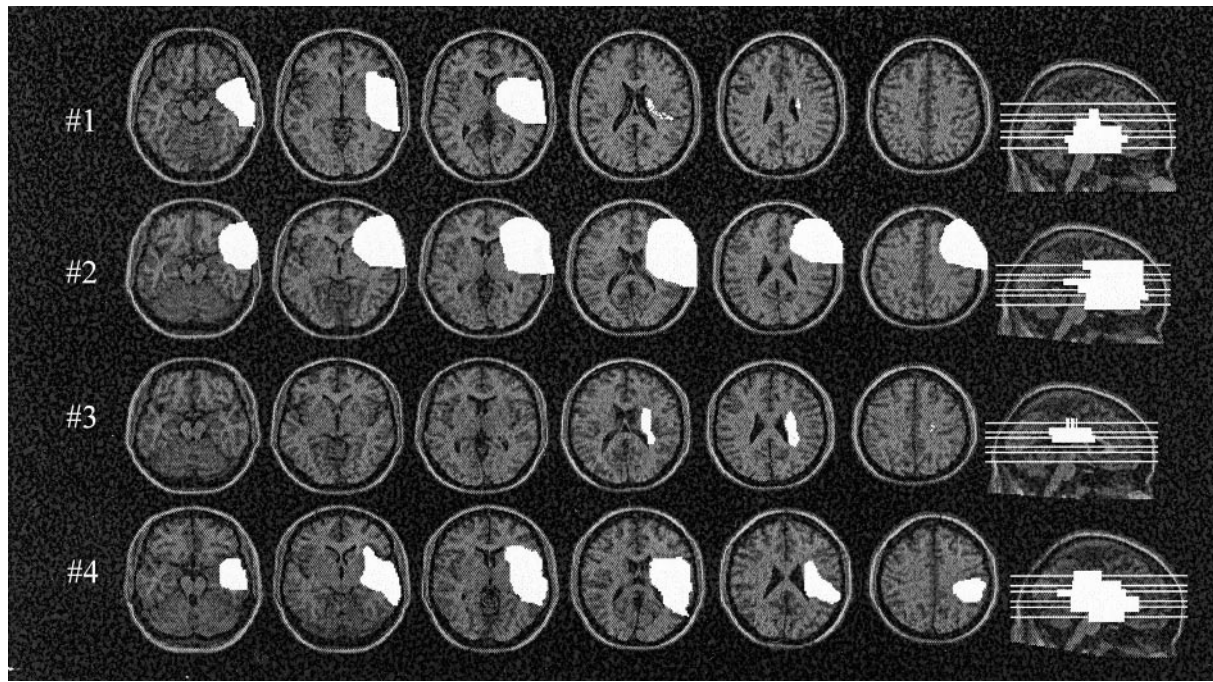


Figure. Reconstruction of patients' brain lesions as documented by CT scan. Lesions were drawn on a standard MRI T1-weighted template (Montreal Neurologic Institute) using MRICro software, available as freeware (<http://www.psychology.nottingham.ac.uk/staff/cr1/mricro.html>).

(no stimulation) were also intermingled. Patients verbally reported their perception on each trial (i.e., "left," "right," "both," or "none"). All patients showed substantial misses of the left contralesional stimulus during bilateral stimulation (table 2). Perception of unilateral left stimuli was good in three patients (Patient 1 = 83% correct; Patient 2 = 89%; Patient 3 = 100%) but impaired in Patient 4 (28%; see table 2). Responses to unilateral right and catch trials were always accurate (>98% for unilateral; 100% for catch trials). Patients were tested for visuospatial neglect and tactile extinction immediately before and after a single 10-minute application of prismatic lenses producing a 20° rightward shift of visual input. During PA, patients sat in front of a touch screen 57 cm away. They pointed to successive visual targets appearing randomly on the monitor at 0° or 10° of visual angle toward the left or the right (90 targets, 30 per position). Patients pointed to

each visual target as quickly as possible using their right index finger, starting from their chest. A horizontal occluding board allowed patients to see only the terminal part of each pointing movement (which enhances PA).

To assess any aftereffects of PA, two open-loop measures were also taken, one before PA (pre-PA) and one after PA (post-PA). During these measures, comprising 10 trials per position, patients could not see the endpoint of pointing movements because the occluding board now contacted the screen.

Results. Prism adaptation was measured by comparing the average pointing error, as recorded by the touch screen, between the first and last five trials of the PA session for each target position. Pointing errors were always larger in the first than the last five

Table 1 Patients' clinical and demographic data

Patient	Age	Lesion	Visual field	Strength	Letter cancellation	Star cancellation	Mesulam cancellation	Line bisection	Visual extinction	Tactile extinction
1	69	T I Th BG Infarct	LHH	4	6/4	—	19/11	7/0	—	+
2	50	F T P W Craniotomy	LHH	1	—	0/0	14/4	26/18	—	+
3	64	W Ic Infarct	LIQ	2	—	5/4	20/16	6/4	—	+
4	57	F T P Infarct	LIQ	4	—	22/5	17/16	1/–5	+	+

All lesions were in the right hemisphere and occurred 4 to 24 months previous to testing.

T = temporal; P = parietal; T = temporal; O = occipital; I = insula; Th = thalamus; IC = internal capsule; BG = basal ganglia; W = subcortical white matter; LHH = left homonymous hemianopia; LIQ = left inferior quadrantanopia.

Strength scores are reported according to the MRC scale for Grading Muscle Strength (score 5 = no deficit). Neglect assessment was performed by means of three standard tests: either Star cancellation or Letter cancellation, line bisection, and Mesulam random shape cancellation.¹ Values represent the number of items omitted on the left side (for cancellation tasks), or the average percentage of rightward (positive values) or leftward (negative values) deviation from the objective midline (for line bisection); values are given for before and after prism adaptation (PA), separated by a forward-slash (i.e., pre-PA/post-PA).

Table 2 Performance (percentage correct) on left tactile stimulation before and after prism adaptation (PA)

Patient (session)	Bilateral (unilateral)	
	Before PA	After PA
1 (rightward shift)	25	46
2 (rightward shift)	11	28
3 (rightward shift)	54	71
4 (rightward shift 1)	22 (28)	44 (56)
4 (leftward shift 1)	22 (33)	22 (44)
4 (rightward shift 2)	11 (33)	28 (61)
4 (leftward shift 2)	16 (39)	11 (44)

Values represent the percentage of correctly reported left tactile stimuli on bilateral (or unilateral; in parentheses, only for patient 4) presentations, before and after PA. Top four rows show results of PA with rightward optical displacement for each patient. Bottom three rows show results for each successive session of PA in Patient 4, one with leftward and two with rightward optical prismatic shift (each session separated by a week). Performance on unilateral right tactile stimulation was flawless before and after PA in all patients.

trials (mean = 18° vs 4° of visual angle; $t(3) = 4.28$; $p < 0.02$), indicating a large correction of the initial pointing error by the end of the PA session (when still wearing the prisms). For the aftereffect of prism exposure, we found that the average open-loop pointing direction (without visual feedback) was more leftward for post-PA than pre-PA (mean = 0° vs 3°; $t(3) = 3$; $p = 0.05$). This was accompanied in all patients by some improvement in neglect tests after PA (see table 1), thus confirming once again its effect on visuospatial neglect.³

Critically, detection of contralesional tactile stimuli during bilateral stimulation improved after PA in all patients (average correct, pre-PA = 28%, post-PA = 47%; $t(3) = 14.3$; $p < 0.01$; see table 2, top four rows). Perception of unilateral left tactile stimuli in Patient 4 (the only patient who showed a clear left deficit even for unilateral stimulation) showed a similar improvement (pre-PA = 28%; post-PA = 56%; $p < 0.04$ by one-tail χ^2).

This improvement in tactile extinction cannot be attributed merely to learning of the tactile task, rather than a specific influence of PA, for several reasons. First, extinction rates were stable over multiple tests performed before the PA protocol in all patients. Second, when comparing the first vs second half within the extinction testing before PA, any trend was for extinction to increase rather than decrease over successive trials. Third, we were able to implement a more extended PA protocol in Patient 4, applying three further PA sessions with the same general procedure and numbers of trials as described previously. Critically, to assess the specificity of the PA treatment, in two of these further sessions we now used a leftward optical prismatic shift (inducing rightward corrections and aftereffects in subjects), whereas in the other, a rightward shift was used again. If the effect of PA on somatosensory deficits depends on the specific direction of PA, left tactile perception should improve only after rightward but not leftward optical prismatic shifts, as previously observed for visuospatial neglect.³ The order of PA sessions, including the first described previously, was right shift, left shift, right shift, left shift, separated by 1-week washout intervals.

Left improvement on unilateral and bilateral tactile trials was present after rightward ($p < 0.05$ by χ^2 for both sessions) but not leftward prismatic shift ($p > 0.7$ for both sessions; see table 2,

bottom four rows). Correspondingly, rightward prismatic shifts induced leftward adaptation and aftereffects in pointing responses (both at $p < 0.05$), whereas the trend for rightward effects from leftward prismatic shifts was unreliable.

Finally, we also assessed visual extinction within Patient 4 before and after each PA session. The computerized task consisted of detecting 15-ms color changes of target squares (1° visual angle) at 10° eccentricity. Visual extinction showed a similar improvement to that found for tactile extinction after rightward (both sessions at $p < 0.05$) but not leftward prismatic shift.

Discussion. Our results show that PA (specifically to a rightward optical shift) can significantly improve perception of contralesional tactile stimuli in neglect patients with right hemisphere strokes. Improvement of tactile extinction was accompanied by a general amelioration of visuospatial neglect on standard clinical tests. This accords with proposals that somatosensory deficits in right hemisphere patients may relate, at least partially, to neglect.⁸ The results also show that the beneficial effects of PA are not restricted merely to visuomotor tasks but can also affect perception in nonvisual modalities in tasks not requiring spatial exploration. PA may have benefited our patients by influencing the high-level, multimodal representations associated with spatial attention,⁹ possibly in the parietal lobe, which can be activated by PA.¹⁰ Its beneficial influences on somatosensory and visuomotor deficits suggest a potential role for PA in rehabilitation of patients with multiple aspects of neglect.

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