IMPLICIT PROCESSING AND LEARNING OF VISUAL STIMULI IN PARIETAL EXTINCTION AND NEGLECT

P. Vuilleumier[1], S. Schwartz[1], M. Husain[1,2], K. Clarke[1] and J. Driver[1]

([1]Institute of Cognitive Neuroscience, University College London; [2]Imperial College School of Medicine, Charing Cross Hospital, London, UK)

INTRODUCTION

Visual extinction and unilateral spatial neglect involve deficits in spatial awareness and attention for stimuli on the side opposite to a brain lesion, typically involving the right parietal cortex. Visual pathways into occipital and temporal cortical areas can be structurally intact. Thus, patients with extinction but no field defect may detect a stimulus presented alone in their contralesional field, but fail to detect the same stimulus when presented with competing stimuli on the ipsilesional side. Several findings suggest that extinguished stimuli can still be unconsciously processed along the structurally spared ventral visual stream, e.g. producing implicit semantic priming effects (e.g. Berti and Rizzolatti, 1992).

However, it remains to be established how far such residual processing can proceed in the absence of awareness, and what its consequences are. The ventral stream pathway into temporal cortex is critical not only for object identification but also for long-term memory of visual objects. Here we asked whether residual processing of extinguished stimuli can produce subsequent implicit or explicit memory traces, even when tested many minutes later.

PATIENTS AND METHODS

We studied 4 patients (3 males, and 1 female; 52, 60, 66, and 83-year-old) with a chronic ischemic stroke, involving the right posterior parietal cortex. All patients had intact visual fields on confrontation testing, stable unilateral left spatial neglect in standard cancellation tasks or line bisection, and reliable visual extinction on bilateral simultaneous stimulation.

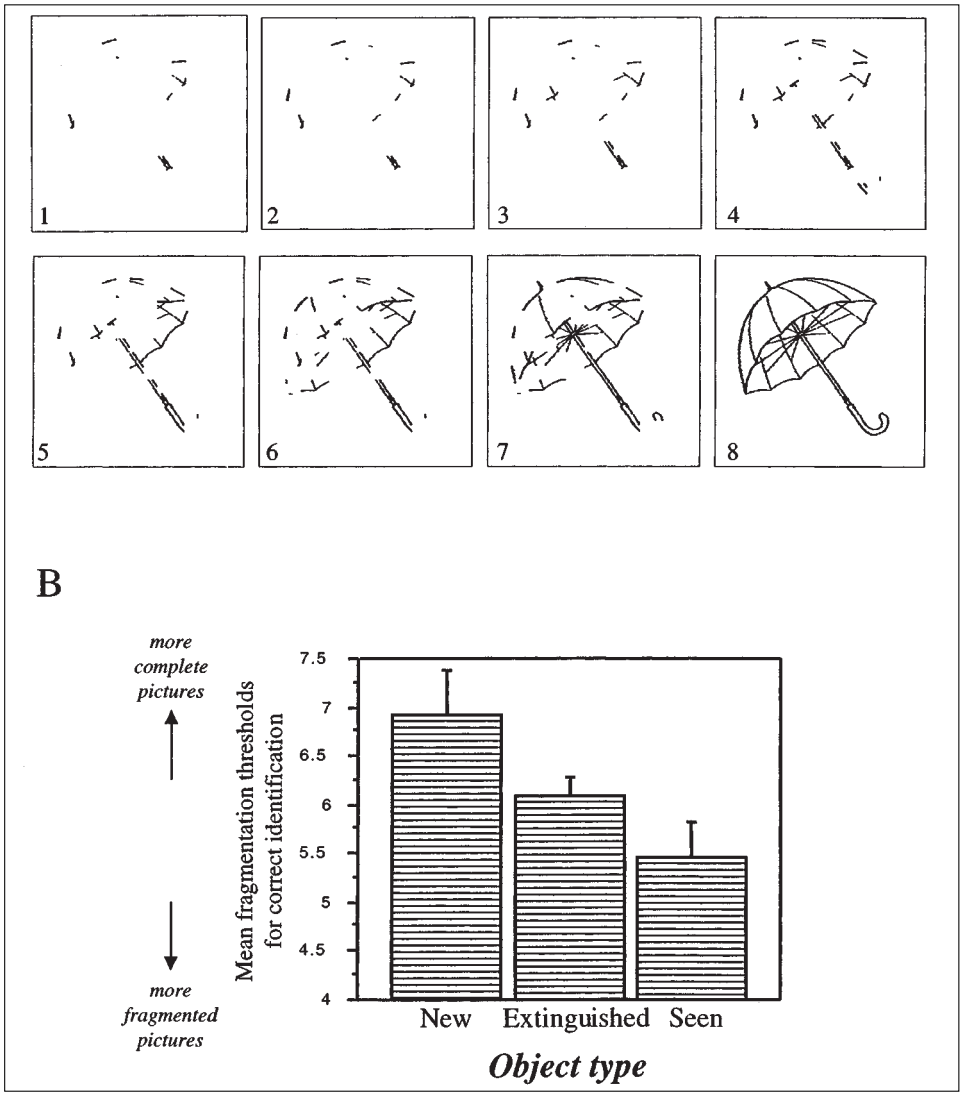
The study was divided into 2 successive phases: a first “study phase” (extinction test), followed by a second “test phase” (direct and indirect tests of memory). Each patient was tested on two separate sessions, using different objects (taken from Snodgrass and Corwin, 1988).

In phase 1, visual extinction was assessed by briefly presenting objects in the right, left, or both fields (size ~3-4°, eccentricity ~ 7-8°), in random order (75-400 ms duration, constant for each subject). Patients had to name the objects without any memory instructions (first session); or had to make indoor/outdoor categorization and memorize them (second session); the implicit memory effects

reported below did not differ between sessions. There were 18 unilateral stimuli (9 in RVF, 9 in LVF) and 18 bilateral stimuli in each session, all presented only once.

In phase 2 of each session, pictures of fragmented objects were shown one at a time, in a stepwise clarification procedure (Warrington and Weiskrantz, 1968), starting with extremely fragmented pictures (level 1), followed by increasingly complete pictures (up to level 8), until the object was correctly identified (Figure 1A). This included 54 "old" items from phase 1 and 20 "new" items.

Finally, once an object was correctly identified, the patients were asked whether they recalled having seen it in the preceding 'study' phase of extinction testing.



Results

In phase 1, as anticipated, all patients showed good detection of unilateral stimuli (mean 4% left missed), but marked extinction of the left-side objects in bilateral trials (mean 82% missed).

In phase 2, an indirect test of memory was obtained for both extinguished and seen stimuli, as compared to new stimuli, by computing the mean fragmentation level at which each object was correctly identified by the patients (Figure 1B). Identification thresholds were better for objects that had previously been consciously seen during extinction testing (mean 5.5 ± sd 0.4) than for new objects (mean 6.9 ± sd 0.5; $p < .01$, Mann Whitney) or extinguished objects (mean 6.1 ± sd 0.2, $p < .01$). Critically, identification thresholds were also better for previously extinguished objects than for new objects ($p < .02$). There was no effect due to different levels of processing at study between the two sessions (i.e. naming vs categorizing stimuli, and incidental vs intentional memory instructions at study).

By contrast, a direct test of recollection in phase 2 showed that explicit recall was null for extinguished objects (5%), being no different to the false-alarm rate for new objects (4%, $p > 0.4$, Fisher's test). Explicit recall was much higher for objects that had previously been consciously seen (75%, $p < .001$), and increased in session 2 due to deeper processing at study under intentional learning instructions.

Discussion

Identification was facilitated for fragmented pictures of objects that had previously been extinguished, as compared to new objects that were never exposed before. By contrast, a direct test of explicit memory showed no significant recall for extinguished stimuli.

These findings indicate that implicit visual learning occurred independent of awareness for these objects at study. This may relate to recent fMRI and ERPs findings of category-specific activation in ventral visual stream evoked by extinguished simuli (Rees et al., 2000, Vuilleumier et al., 2001), suggesting that such activation can produce implicit memory traces lasting many minutes after stimulus exposure.

However, identification thresholds were even better for objects that were previously seen consciously, compared with either new or extinguished objects. This suggests that attention and awareness at encoding can enhance the subsequent learning effects revealed in indirect memory tests. Recent imaging results in a parietal patient show that awareness of contralesional stimuli, as opposed to extinction, is associated with stronger activation in ventral temporal areas (Vuilleumier et al., 2001). Such increased activation during study might mediate the enhanced implicit learning effects at test.

These results suggest that unconscious residual processing in extinction can induce enduring changes in intact visual areas and influence perception of subsequent stimuli (see also Vuilleumier and Sagiv, 2001). Future research could

examine whether such learning effects for extinguished (or neglected) stimuli might be exploited in rehabilitation.

References

BERTI A and RIZZOLATTI G. Visual processing without awareness: Evidence from unilateral neglect, *Journal of Cognitive Neuroscience, 4:* 345-351, 1992.

REES G, WOJCIULIK E, CLARKE K, HUSAIN M, FRITH CD and DRIVER J. Unconscious activation of visual cortex in the damaged right hemisphere of a parietal patient with extinction, *Brain, 123:* 1624-1633, 2000.

SNODGRASS JG and CORWIN J. Perceptual identification thresholds for 150 fragmented pictures from the Snodgrass and Vanderwart picture set, *Perception and Motor Skills, 67:* 3-36, 1988.

VUILLEUMIER P and SAGIV N. Two eyes make a pair: Facial organization and perceptual learning reduce visual extinction, *Neuropsychologia*: in press, 2001.

VUILLEUMIER P, SAGIV N, HAZELTINE E, POLDRACK R, RAFAL R and GABRIELI J. The neural fate of seen and unseen faces in visuospatial neglect: A combined event-related fMRI and ERP study of visual extinction, *Proceedings of the National Academy of Sciencesi USA, 98:* 3495-3500, 2001.

WARRINGTON E K and WEISKRANTZ L. New method of testing long-term retention with special reference to amnestic patients. *Nature, 217:* 972-974, 1968.

Dr P. Vuilleumier, MD, Institute of Cognitive Neuroscience, University College London, Alexandra House, 17 Queen Square, London WC1N 3AR, UK. Email: p.vuilleumier@ucl.ac.uk .