farms, these farms are rapidly being converted to input-intensive monocultures [2,3]. Thus, it is imperative to highlight the ecological function of shade coffee farms, not only in providing refuge for native fauna, but also in preserving habitat connectivity and gene-flow processes essential for reforestation by native tree species.

Supplemental Data

Supplemental data are available at http://www.current-biology.com/supplemental/S0960-9822(08)01496-6

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Intact navigation skills after bilateral loss of striate cortex

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A patient with bilateral damage to primary visual (striated) cortex has provided the opportunity to assess just what visual capacities are possible in the absence of geniculo-striate pathways. Patient TN suffered two strokes in succession, lesioning each visual cortex in turn and causing clinical blindness over his whole visual field. Functional and anatomical brain imaging assessments showed that TN completely lacks any functional visual cortex. We report here that, among other retained abilities, he can successfully navigate down the extent of a long corridor in which various barriers were placed. A video recording shows him skillfully avoiding and turning around the blockages. This demonstrates that extra-striate pathways in humans can sustain sophisticated visuo-spatial skills in the absence of perceptual awareness, akin to what has been previously reported in monkeys. It remains to be determined which of the several extra-striate pathways account for TN's intact navigation skills.

We investigated the residual vision for locomotion in TN, an unusual subject as the only available case in the literature with selective bilateral occipital damage (but see also [1] for a report on intact fear conditioning in a similar patient). TN suffered the first stroke that damaged his occipital cortex unilaterally, and some 36 days later a second stroke occurred that damaged the occipital cortex of the other hemisphere (Figure 1A). He was initially studied by Pegna *et al.* [2] while in hospital in Geneva after his second stroke. These first observations on TN showed affective blindsight in response to facial expressions, as indicated by condition-specific amygdala activation for emotional expressions of fear, anger and joy compared to neutral. We studied TN behaviorally, electroencephalographically and with brain imaging techniques, including diffusion tensor imaging (DTI), in Tilburg and Maastricht.

No active visual cortex could be found in TN in response to a range of visual stimuli in a series of imaging sessions, including different sessions of retinotopic mapping. Because it was impossible to control his fixation, one could not be certain that absolutely all visual cortex had been destroyed or inactivated. Nevertheless, it is a highly reasonable surmise that this was so given the consistently negative imaging

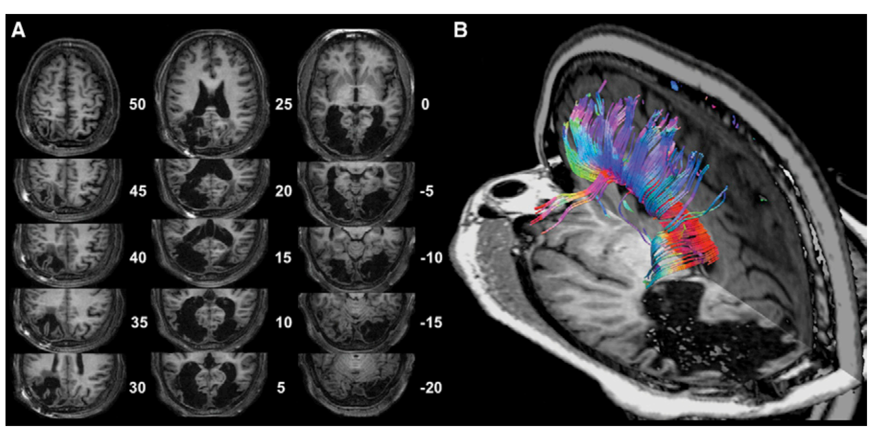

Figure 1. Anatomical description of the lesions in TN.

(A) T1-weighted MRI (axial view) showing TN's lesions and confirming bilateral destruction of the visual cortex (Talairach z-coordinates are given; left is left, right is right). (B) Fibers of the corpus callosum (CC) in TN (view from left-posterior). While seed points were placed in the entire CC, only fibers originating from the genu and body of the CC were found. In the splenium, no callosal fibers were detected. Only infero-frontal running fibers could be delineated, which do not belong to CC.

findings, and it is further supported by a computer-based perimetry test in which no sparing was found.

Behaviorally, TN was blind across the whole visual field. He walked like a blind man, using his stick to track obstacles and requiring guidance by another person when walking around the various laboratory buildings during testing. He was not cognitively impaired except for some mild word-finding difficulty. Psychophysical tests specifically designed to assess the blind fields of subjects with cortical blindness [3,4], including detection of the presence/absence of big targets in an alternative forced-choice task, proved completely negative; no residual visual function could be found. He showed some evidence of visuo-motor integration in spatially-guided reaching. Furthermore, he was able to discriminate the difference between a long rod randomly placed in horizontal or non-horizontal positions, with a difference threshold of approximately 25°. This, as it happens, was one of the very first behavioral tests that revealed DB's residual capacities in informal testing [5,6].

The DTI results (carried out by Rainer Goebel and colleagues in Maastricht) showed a severe loss of posterior callosal fibers connecting the two occipital lobes, as assessed by near-zero fractional anisotropy values (Figure 1B). In contrast to cases of unilateral occipital hemianopia, where cross-callosal processing appears to be important in linking an input to the damaged hemisphere with the homologous brain regions in the intact hemisphere [7], in TN the possibility of such cross-hemispheric support appears to be lost, not surprisingly given that both of his hemispheres have been damaged.

In view of these negative results, we decided to test his residual visual abilities for locomotion and navigation. We constructed a complex obstacle course consisting of boxes, chairs, and so on, arranged randomly along a long corridor, without any person to guide him and with the removal of his walking cane. An experimenter always followed behind him during his traversing the course in case of a fall or collision, which seemed a real possibility given his clinical blindness. Astonishingly, he negotiated it perfectly and never once collided with any obstacle, as witnessed by several colleagues who applauded spontaneously when he completed the course. This was filmed and is available as a video clip in the Supplemental Data available on-line with this issue.

There is evidence suggesting that blind or blindfolded sighted subjects are able, to some extent, to use the natural auditory obstacle sense to locate a travel path, although auditory guidance is notably inferior to visual guidance and deteriorates markedly when small targets are used to define the travel path [8]. Therefore, the theoretical possibility that TN was guided by echolocation abilities from reflection of sound waves, rather than by unacknowledged visual inputs, cannot be totally ruled out. Nevertheless, this appears as an extremely remote possibility in the present case, as neither TN nor the experimenter following behind him emitted any detected sound during navigation that might have generated sound waves reverberation from the objects laying on the floor. Moreover, the spatial resolution that can be obtained through any echolocation capacity in humans is significantly below that necessary to explain TN's accurate navigation performance through small objects, as can be observed in the video [9,10].

Similar findings to these were reported by Humphrey [11] for a monkey, 'Helen', with bilateral striate cortical lesions, which at present remain the only antecedents of our results. Helen successfully avoided various obstacles in an open-field test (as illustrated in a video clip downloadable from the web link: http://viperlib.york.ac.uk/login_pop.asp?filename=Helen3.mpg&thumb_id=2582). The lesion was found not to be absolutely complete in one hemisphere, leading to the surmise that there was a small region of intact vision in the far periphery of the right visual field. This could not have accounted for all the varieties of residual visual functions in Helen, although there perhaps remains some ambiguity in this regard for her obstacle course performance. Given the consonance with the animal research background and the extreme rarity of cases with complete cortical blindness in humans, this striking observation will serve as a take-off point for future studies, when and if other patients will come to light.

Supplemental Data
Supplemental data are available at http://www.current-biology.com/supplemental/S0960-9822(08)01433-4

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