

Mirror agnosia

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SUMMARY

Normal people rarely confuse the mirror image of an object with a real object so long as they realize they are looking into a mirror. We report a new neurological sign, 'mirror agnosia', following right parietal lesions in which this ability is severely compromised. We studied four right hemisphere stroke patients who had left visual field 'neglect'—i.e. they were indifferent to objects in their left visual field even though they were not blind. We then placed a vertical parasagittal mirror on each patients' right so that they could clearly see the reflection of objects placed in the (neglected) visual field. When shown a candy or pen on their left, the patients kept banging their hand into the mirror or groped behind it attempting to grab the reflection; they did not reach for the real object on the left, even though they were mentally quite lucid and knew they were looking into a mirror. Remarkably, all four patients kept complaining that the object was 'in the mirror', 'outside my reach' or 'behind the mirror'. Thus, even the patients' ability to make simple logical inferences about mirrors has been selectively warped to accommodate the strange new sensory world that they now inhabit. The finding may have implications for understanding how the brain creates representations of mirror reflections.

The manner in which the brain deals with mirror reflections has always been a source of fascination for psychologists (Corballis 1991; Gregory 1996), philosophers (Kant 1953) and logicians (Carroll 1994; Gardner 1964). Normal adult humans rarely confuse a mirror reflection for a real object as long as they know they are looking in a mirror, e.g. if you see an approaching car in your rear-view mirror, you accelerate forwards, not backwards. We now report a new neurological syndrome, 'mirror agnosia', following right parietal lobe lesions in which this ability is severely compromised.

Hemispatial neglect is one of the most enigmatic syndromes in neurology and it usually occurs following a right hemisphere stroke (Riddoch 1935; Critchley 1996; Heilman *et al.* 1985; Kinsbourne 1994; Halligan & Marshall 1994). Patients tend to ignore everything on their left side even though they can see the same things perfectly clearly if their attention is drawn to them, i.e. their sensory apparatus is quite normal. For example, the patient may eat from only the right side of her plate, she may apply make-up only on the right side of her face or, when asked to draw a flower, she draws only half of it (Critchley 1996)! Remarkably, when asked to describe a familiar visual scene from memory, the patient will sometimes mention only the landmarks and objects on the right side of the scene, neglecting the left side of the internally generated image (Bisiach & Luzzatti 1978). The experiment we describe here suggests that the neglect runs deeper than generally supposed, and can even affect the patient's ability to make simple deductive inferences about certain aspects of the world.

We studied four patients—OS, BT, MR and JR. OS was 67 years old with a CT-confirmed right parietal infarct. BT was 63 years old with an MRI-confirmed right parietal-occipital CVA. MR was 87 years old with a CT-confirmed right temporal-parietal infarct. JR was 81 and had a CT-confirmed infarct in the territory of the right middle cerebral artery. OS was tested two years after admission; BT, MR and JR were tested one week after admission. The left hemi-neglect (as revealed by line bisection, clock drawing and line cancellation) was dense in BT and JR, and moderate in OS and MR. A mental status check revealed all four patients to be mentally quite lucid (serial twos, orientation in time and place, three objects, etc.) with no hint of dementia, aphasia or amnesia; indeed they seemed quite conversationally fluent (at least by American standards) and intelligent at the time of testing. All patients also had a left hemiplegia and hemi-anaesthesia. OS also had a left hemianopia and MR had visual extinction in response to double simultaneous stimulation. None of the patients had neurological or radiological signs of left hemisphere involvement.

After chatting with the patients informally, we propped a mirror up vertically on the right side of the bed or wheelchair with one experimenter (usually VSR) standing behind it. The mirror was 2 ft tall and 1.5 ft wide (1 ft \approx 30 cm). It was 1.5 ft from the patient's midline and parallel to the sagittal plane so that its right edge was close to her right shoulder. She was asked to turn her head and eyes to the right to look into the centre of the mirror, so she could clearly see the mirror reflection of the people/objects that were on the left side of the bed or wheelchair. It was

quite clear that it was a mirror, since it had a wooden frame and dust on its surface. Our question was: how would the patient react to objects seen only in the mirror? Would it help overcome her neglect of these objects since the *sensory input* was now coming from the right side, or would she ignore the reflection as well, especially if her brain carries out the left–right transposition before the stage at which neglect occurs in the brain?

To ensure that the patient knew she was looking in the mirror, one investigator (VSR) stood on the patient's right behind the mirror and asked: 'what is this I am holding?', to which each patient replied 'a mirror'. We then asked the patient to describe her eye-glasses, lipstick, etc., while looking into the mirror. Upon receiving a cue, a second investigator standing on the patient's left side, held out a pen or candy bar toward her so that it was well within the reach of the patient's non-paralysed (right) hand but entirely within the neglected (left) visual field—about eight inches (20.4 cm) below and to the left of the patient's nose. The size and location of the mirror was adjusted to allow the patient to see not only the candy bar, but also the second investigator's arm, torso and shoulder in the mirror. Also, since the patient was looking at the centre of the mirror, the reflection of the candy was normally to the *right* of fixation, i.e. in the patient's non-neglected field. The experimenter (VSR) then asked the patient, 'Do you see the pen?' and when she nodded and said 'yes', the experimenter added, 'Okay, reach out and grab the pen please'. The remarkable result was that the patient used her right hand to reach without hesitation straight into the mirror and kept banging repeatedly into the mirror (Ramachandran *et al.* 1996). When asked what was going on BT said, 'It's not in my reach' or 'You are not holding it within my reach'. OS said, 'It's behind the mirror' and actually tried repeatedly to get her hand behind the mirror frame! Patient MR also tried groping behind the mirror on several trials claiming that 'the object is behind the mirror' or 'inside the mirror'. On several occasions she tried to grope VSR's tie or belt-buckle while he stood behind the mirror. This happened continuously for about 20 s on any given trial. Since the experiments were done in a clinical setting, it was not always possible to follow identical protocols (e.g. number of trials) on all patients, but we were able to repeat the experiment six times (three times each day on two consecutive occasions) on BT, a total of ten times on two consecutive occasions on OS, nine times (three consecutive days) on MR and three times on JR, always with the same outcome. And before each testing session we always verified that the patient knew she was looking in a mirror by asking her what she was looking at and also by asking her to describe her face, glasses, etc. Since the patient can see the mirror clearly but behaves as though it does not exist, we propose to call this syndrome 'mirror agnosia'.

We also tried placing the mirror at arm's length in front of the patient—in the coronal plane. This time, when the candy appeared just behind and above

the patient's right shoulder (but just outside the patient's visual field), the patient saw it in the mirror and her hand went straight behind her to grab it. This was repeated eight times on OS (two separate testing sessions) and four times (on two consecutive days) on BT, once on JR and ten times on MR. On all trials for all patients (except six trials in MR) the patient's hand went unerringly and without hesitation for the real object, as expected. (MR touched the mirror on many trials but usually corrected herself quickly.) The difference between the sagittal mirror trials and coronal mirror trials in the first three patients is important for it suggests that at least in some patients the deficit observed with the sagittal mirror could not have been the result of a general confusion with mirrors or with reaching ability. Also, as an extra precaution, we repeated the experiment on seven age-matched controls: stroke patients who had a right hemiplegia and no neglect. None of them had any difficulty reaching correctly for the object that was visible only in a mirror (correct reaching on all of 28 trials; $n = 7 \times 4$ trials). Indeed, the task was sufficiently easy that even one of the author's (VSR's) two-year-old son accomplished it effortlessly.

We were concerned that the tendency to reach into the mirror may have been the consequence of a syndrome called 'directional hypokinesia' (Heilman *et al.* 1985)—a general reluctance to make movements into the neglected (left) field. However, this cannot explain what we observed for four reasons: first, the patients had no difficulty following instructions such as 'touch your left shoulder', 'touch your left elbow' or 'touch your left knee', etc.; second, when we asked two of the patients to 'point as far left to your left as possible', their performance was identical to normal people on eight trials ($N = 4 \times 2$); third, even if directional hypokinesia were contributing to the effect in some cases, one would expect the patients to simply keep still; one certainly would not expect them to reach repeatedly into the mirror or *behind* it; and finally, the verbal remarks of the patients made it clear to us that the patients believed quite literally that the pen was inside or behind the mirror; e.g. 'You are not placing it within my reach, Doctor', 'It is inside the mirror', or 'It is behind the mirror'. Such remarks were made repeatedly—not just once or twice.

One could argue, of course, that the 'coronal' and 'sagittal' trials are not strictly comparable since the mirror image alone is visible in the former whereas both the real object and the mirror image are simultaneously visible in the latter. If this were influencing our results, however, one would expect it to produce the opposite effect to what we found, i.e. since *only* the mirror image is visible in the coronal trials one might have expected an even greater tendency to reach into the mirror, but in fact the first three patients always reached correctly for the invisible object over their right shoulder.

Finally, we verified that all four neglect patients had no radiological evidence of left hemisphere involvement, no Balint's syndrome, no autotopagnosia (body part confusion), apraxia (inability to follow

simple commands), left-right confusion (e.g. they could accurately obey commands such as 'Touch your left ear', 'Touch your right knee') and no allæsthesia (targets in the left visual field mislocalized systematically to the right). Also, BT, OS and JR had no anosognosia (denial) at the time of testing, but MR denied that her left arm was paralysed.

Two interpretations of mirror agnosia are possible, that are not mutually exclusive: (a) the syndrome may be a specific consequence of the neglect. It is as though the patient was saying to herself 'Since the reflection is in the mirror, the pen must be on my left. But left does not exist in my world, therefore it must be inside the mirror', however absurd this may seem to us with our intact brains; and (b) alternatively, it may not be a consequence of neglect, even though it is usually accompanied by neglect. Instead, it may be a striking manifestation of the subtle deficits in spatial abilities that occur following parietal lobe lesions. Responding correctly to a mirror image requires the creation of a rather peculiar form of dual representation or 'mental diplopia', and this subtle ability may be compromised by the right parietal lesion. This would explain why some patients, e.g. MR, also reach repeatedly into the coronal mirror.

Several additional questions remain. Is the incorrect response to the command 'Grab the pen' linked in any way to the literal mindedness and difficulty with metaphorical language use that characterizes some right hemisphere patients? Is mirror agnosia a consequence of neglect, or can it be disassociated from neglect? Would the confusion also extend to the patient's own body parts—e.g. can she use her right hand to reach for her paralysed left hand while using visual guidance from the mirror? Would repeated verbal correction by the experimenter eventually eliminate mirror agnosia and, if so, can the procedure be used to accelerate rehabilitation from neglect? Is the misreaching mainly mediated by a damaged 'dorsal stream'? If so, would it still occur if the patient were to close her eyes for a few seconds before attempting to grab the pen? And finally, would somatoparaphrenia, the tendency to regard one's own left hand as 'alien', be corrected by the mirror?

Whatever the ultimate interpretation of mirror agnosia, it provides a new experimental probe for exploring right hemisphere deficits and for understanding the neural representation of mirror images in the brain. In particular, the syndrome seems to reveal a 'default' localization of the object to the space behind the mirror, the naive visual perception overriding the cognitive knowledge of mirror reflection. Indeed, the most surprising aspect of the syndrome is not just the patient's reluctance to reach to the left, but her repeated attempts to go behind the mirror and her outlandish remarks, 'It is behind the mirror' or 'Inside the mirror'—i.e. in spite of being mentally

lucid the patient is apparently unable to even *intellectually deduce* that she should search for the object on the left, and that it is pointless to reach for the reflection in the mirror. (Such confusion ordinarily occurs only in animals and very young babies (Gregory 1996).) Even the patient's belief systems and ability to reason intellectually about such matters have become selectively distorted to accommodate the strange-looking glass world in which they now find themselves trapped. It is remarkable that such a domain-specific tolerance for absurdities can be provoked by the mere use of a mirror. (Recall that the patients are lucid in other respects.) Thus, the study of neglect, anosognosia (Ramachandran 1996) and other allied neurological syndromes may actually enable us to explore the representation of propositional knowledge and beliefs in the brain; a new field of science for which the name 'experimental epistemology' (Ramachandran *et al.* 1996) might be appropriate.

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