

Processing of reflected mirror images in the brain - Physiological basis, pathomechanisms and therapeutic options

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Abstract

Human brain has several abstract functions which helps man to plan for future, dream, create etc. Mirror image processing is believed to take place by a unique phenomenon of mental diplopia not seen in lower animals. This phenomenon gets altered in several disease states resulting in several types of perceptual problems and also these perceptual delusions seem to have therapeutic effects in some disabling diseases.

The exact mechanism of Mirror image processing in the human brain and the real pathomechanisms underlying treatment effects are mysterious.

Introduction

The earliest mirrors in the world were probably the water sources. The foolish lion and clever Rabbit story and Lord Narasimha fighting with his reflection after the killing of Hiranyaha shibu are examples for this. 8000 years ago, mirrors were made with volcano glasses in in Turkey and later Mesopotamia and China.

Reflected image processing is a unique function of brain seen in humans and highly evolved Chimpanzees. Children below 2 years also are not capable of recognizing reflected self-images as their own reflection. Human visual system develops a perceptual constancy or invariant representation of the seen world and its mirror representations [1]. This is said to be a function of left occipital temporal cortex. But literate adults have more difficulty in recognizing mirror image of letters than objects raising questions regarding the role of literacy [2]. Involuntary rotation of words and letters is seen in patients with primary reading difficulty in the absence of mirrors. This rotation takes place naturally and unconsciously in mirrored letter recognition. For self-face recognition Keenen et al. [3] used and projected different human faces and the test person had to raise the hand for the self-face. It was found that left hand used shorter time to rise than right for self-face indicating probable right hemisphere dominance for reflected self-face recognition. Very early onset of face specific orienting response is seen in fusiform area even at birth. In children recognizing the faces of others in mirror is learned early as they can compare the real person in front of them and match it with the virtual reflection in the mirror. With reference to self, they are anxious as they're unable to understand "who is in the mirror", as no other person to whom they can turn for the real image is visible. They show gestural imitations, touching themselves and slowly learn. Last learned reflected image is mirrored object recognition in real space.

Physiological basis of reflected image processing and recognition

A ray of light travelling horizontally towards a reflecting surface of a plane mirror, if it makes angle at point of incidence of zero, it retraces its path but if there are angulations it gets reflected. If these lines are traced backwards, they meet at a point, but this meeting is not true or real and the image thus produced is virtual, it is erect, of the same size, same distance as that of the object from the mirror and it is laterally inverted. This is because, when we look at our self in a mirror, it appears as if a person is standing behind the mirror at the same distance and facing us. Therefore, it is a front to back inversion, as mirrors just reflect what is in front of it [4]. We imagine it as left right reversal as we believe the image to be 'real our self' and not virtual. Mirrors are in use from time immemorial and continues to do so, even now, to see spaces normally which are not accessible for direct vision including equipment used in advanced medical, astronomical and day to day life. When child starts understanding these images, probably the mirror images also become incorporated in the body schema, which is termed as mental diplopia of self-image. Unique processing is needed to get a proper construct of these images. Mirror images have kinaesthetic cues of the real self, expectation pathways related to self-image as they are real time images and affect related (emotion) circuits are activated. Lot of visuomotor

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transformations is needed to locate the reflections to its source. Mental diplopia is the normal situation where any person seeing an image recognizes both with a dual representation one for the real and other for image. After the formation of visual image of the reflected mirror image, cognitive understanding is involved in recognizing the image as from visual field directly opposite to it. Failure in this mechanism, which is needed for the understanding that it is one's own reflected image, causes mirror image agnosia. Errors in recognition occur either due to wrong knowledge or wrongly applied knowledge. Efficiency of excellent nature is seen in day to day visual information processing but several levels of conceptual knowledge of semantic, phonological and otherwise involving repeated top down utilization of knowledge resources are involved.

Hypothetical disease associations

High incidence of left handedness and mirror writing is seen in children with dyslexia. Dyslexia is a specific disorder causing significant impairment of reading ability unexplained by any kind of deficits in general intelligence, learning opportunity, motivation or sensory acuity. Males are affected more with some features of dominant hemisphere involvement [5]. Atypical lateralization, defect in segmenting phonemes in the visual pathway, (magnocellular system), multisystem deficits where brain is incapable of performing tasks requiring rapid temporal succession are considered as probable cause. During visual stimuli appreciation, there is rotation for constancy in three-dimensional appreciation. But involuntary rotation without mirrors could be causal in dyslexia.

Mirror agnosia is a situation where the person is unable to use mirror information in interpreting the seen world. Ramachandran et al. [6] described four patients who had left homonymous hemianopia and when a reflection of an object to the patients left was seen by the patient in a mirror held in his seeing field and was asked to localize the object, he localized it inside the mirror. This changed when the mirror was moved in front of the patient indicating that it might have been due to neglect. Another study showed the same phenomena in persons without field defect and had persistent defect in mirror image recognition, irrespective of where the mirror was stationed. The site of pathology in mirror agnosia is in the inferior posterior parietal lobe [5,6]. Mirror ataxia was the term used to describe a group of patients who had slowly learnt to redirect their movement to real object but with directional errors. The structure involved in these phenomena was found to be anterior intraparietal sulcus. The term mirror apraxia indicates all types of difficulty reaching to objects presented through a mirror and abnormality is located in posterior parietal cortex [7,8]. Patients who go behind the mirror are probably trying to solve the mystery of the optical illusion. In spite of knowledge that the object is behind, some patients still search behind the mirror indicating the problem is in visuomotor transformation process needed for motor control due to dissociation between explicit knowledge of object in space and implicit ability to interact with mirrors. This was described in patients with dementia as early as 1890 by Binkofski F [8,9]. Ajuriaguerra et al. [10] postulated that recognition of mirror images requires both recognition and dissociation from our living body and their related counterparts. Alzheimer patients sitting in front of mirror and talking to their images are also reported [11]. A phenomenon of de-realization and depersonalization in patients with schizophrenia is akin to mirror agnosia, where the patient is unable to differentiate real from unreal [12,13]. Mirror behaviour disintegration is in three forms, first group, who could not recognize themselves, 2nd who accept after repeated explanation and 3rd group who recognize after the second

presentation of mirror [14]. They reported that the severe group (1st Group) suffered severe visuospatial disorientation. The patients may have fixed perceptual indicators and looks for objects exactly where they see it irrespective of it being virtual or real, i.e., concrete understanding without abstract interpretation, they suffer from failure of utilization of mirrored space. Mirrored self-misidentification delusion is a situation where the person cannot recognize their own image. This is seen in patients with dementia and schizophrenia [15]. This is an example of a monothematic delusion. All patients with prosopagnosia do not show this phenomenon and hence it is considered to have a delusional content and there can be perceptual abnormality at the background. Evidence for remission and relapse of this symptom is also reported [16]. Preserved ability to recognize photo in some of these patients is reported indicating the specificity of the symptom [17].

Delusional misidentification is the term given to a group of disorders characterized by delusory belief regarding the identification of self, places and objects. Mirror agnosia in right occipital infarct is reported with left visual neglect and right mirror agnosia. Here the hypothesis is nothing is seen on left field. Image seen is believed by brain to be inside the mirror [18]. The right parietal infarct fails to produce the needed physiological mental diplopia in recognizing the mirror image as virtual resulting in mirror image agnosia [18]. According to a study by Beis et al. [17] his patients with cerebrovascular accident having mirror agnosia couldn't modify their behaviour even after object was clearly shown in real space but patients with mirror ataxia on the contrary learned to reach the real object easily. Therefore, they postulated complete defect in mirror image processing causes mirror agnosia and incomplete lesions cause mirror ataxia. Defect in analysing non-image clues due to hemineglect is attributed as causal in patients unable to locate the contra-lesionally located images. They used a second mirror to re-invert the image of the 1st mirror. They were told to grasp cubes kept at the table looking at the mirror image. Patients with left hemi neglect picked partially and haphazardly, the cubes on the left field but those with right hemi neglect made fewer omissions in the right field [19]. Therefore, a role for spatial reference appears, possible egocentric (personal) vs ergo centric (extra personal) as well as far vs near space. Reflected self-images processing is likely to involve in real time distinct data-linking circuits in the right parietal lobe, and is more common with posterior dementias [20,21].

Mirror images in treatment

Mirror image-based tricking of the brain has been used for pharmacosparring effect in many conditions.

Phantom limbs

These are amputated limbs which are not forgotten by the brain. Therefore, they get sick, painful, paralyzed and as they really do not exist, the treatment is difficult. Patient is made to sit in front of a mirror box 'virtual reality box' and looking at the mirror image of the normal limb movement's makes patient feel as if the affected limb is moving. This illusion might be breaking the Hebbian circuits in the brain which cause pain and is described as a form of synesthesia as sometimes patient has to see the mirror image to get relief [20]. In trigeminal neuralgia massaging the normal side while the patient watches in mirror is found to be useful [21]. Mirror therapy is also useful in complex regional pain syndromes. In patients with cerebrovascular accidents, mirror therapy is used with the hypothesis that the areas in the brain involved in movement planning and execution may be active during action imagination too. Mirror induced feedback improves motor

imagery. This may improve plasticity and thus repair. Patients are asked to watch their unaffected hand movements in reflection and this improved movement of the paralyzed limb. The principles believed to be operating are virtual reality and motor imagery causing functional reorganization in the brain by restitution plasticity.

Conclusion

The exact mechanism of Mirror image processing in the human brain and the real pathomechanisms underlying treatment effects are as mysterious as everything about the human brain. Human brain is very much more evolved than any other living thing and can-do abstract things including dreaming, creating a virtual world for oneself. Therefore, mental imagery has key role in disease causation as well as prevention and cure. The future of therapeutics may lie in switching on these mechanisms but not drugs and surgeries.

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