


Mind, Brain & Behaviour 1  
Behavioural Neuroscience



The neural correlates of attention  
and consciousness

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## Learning objectives

- Understand the neural pathways that subserve unconscious visual perception in 'blindsight'
- Explain the concept of selective attention
- Outline how the effects of spatial selective attention can be measured experimentally
- Describe the phenomena of 'inattention blindness' and 'change blindness'
- Explain the syndrome of unilateral spatial neglect and provide an example of unconscious perception of neglected stimuli

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## The concept of attention

- *'Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others...'*



William James (1907)

The concept of **attention** has proven remarkably difficult to define. Most people have a general intuition of what attention is, but these ideas do not always conform to our understanding based on empirical evidence derived from experimental psychology and neuroscience. The view proposed by William James more than 100 years ago was as follows:

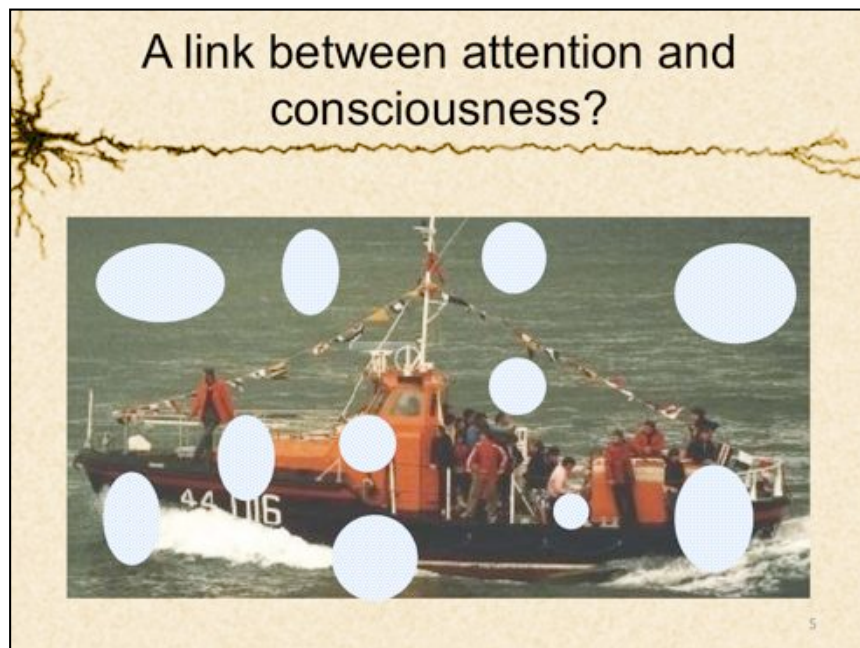
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According to William James, then, attention can be considered as that set of processes used by the brain to select stimuli and actions that are currently relevant for controlling ongoing behaviour, and to inhibit stimuli and actions that are currently irrelevant.

## A link between attention and consciousness?



What role does attention play in determining conscious perception? In this demonstration, you are required to find the small differences between two nearly identical images. During the switch from one image to another, a number of small **noise-masks** appears briefly. This masking pattern does not directly cover any of the changes between the two scenes, but it does have the effect of **capturing attention**, thus making it less likely that your attention will be grabbed by the transient visual signals associated with the changed objects themselves.



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In this slide some of the items that changed have been circled. How many changes did you notice?

Note that once your attention has been drawn to the location of the changed items, it now becomes much easier to spot the changes in the original dynamic display. Your brain now has a representation of the location and identity of these changes in **visual short-term memory** (a set of processes that enables storage of a limited amount of visual information over a relatively short duration).





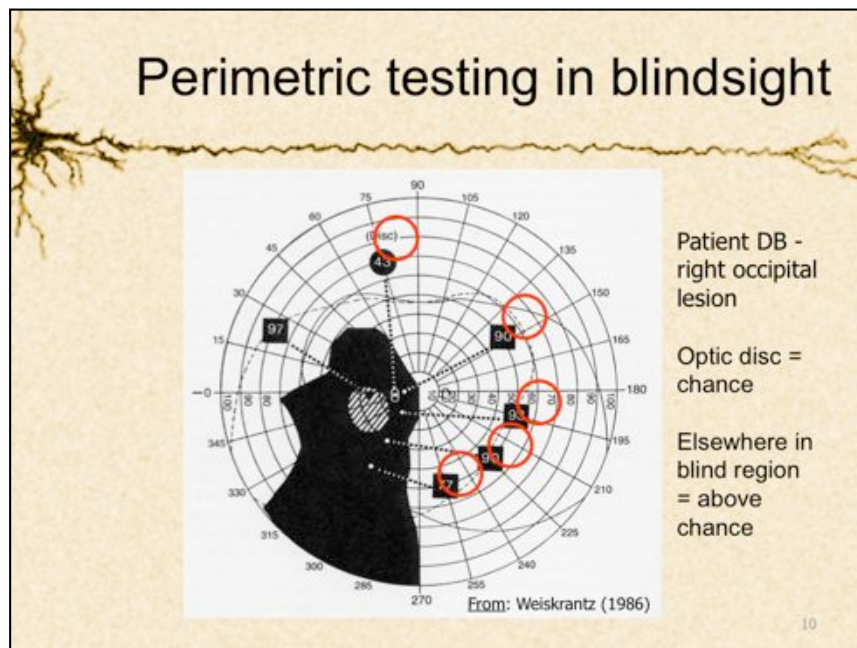
## Blindsight - a disorder of conscious vision

- Occurs following unilateral damage restricted to the primary visual cortex
- Above-chance visual performance in the 'blind' hemifield
- Patient may show preservation of:
  - pupillary reflexes
  - manual and saccadic localisation
  - wavelength & motion discrimination
  - orientation & shape discrimination

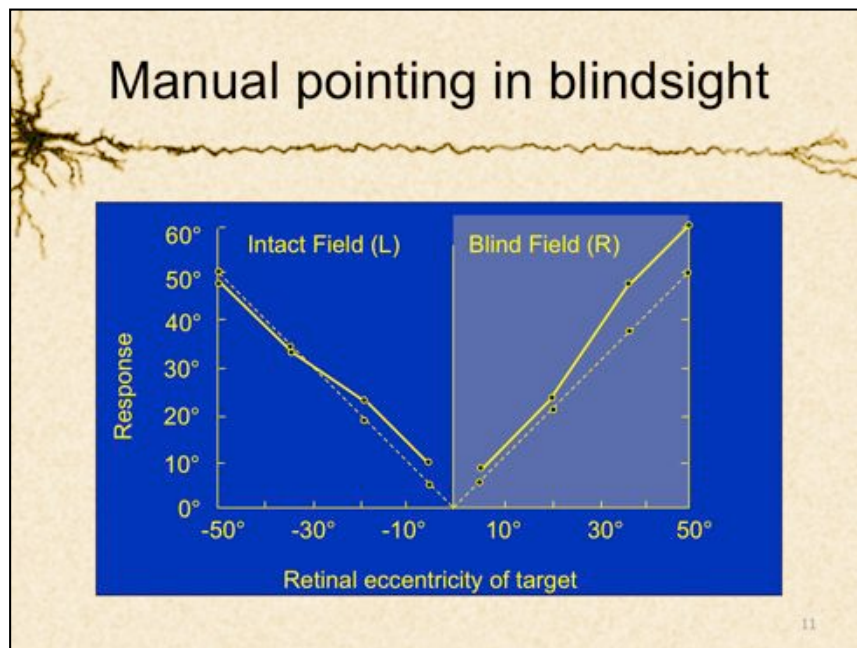
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Similar preservation of visual abilities has been reported in studies of humans with unilateral or bilateral lesions of area V1. Weiskrantz and his colleagues (Sanders, Warrington, Marshall, & Weiskrantz, 1974; Weiskrantz, Warrington, Sanders, & Marshall, 1974) were the first to demonstrate residual visual functioning in a patient with surgical ablation of primary visual cortex. They coined the term **blindsight** to denote such preserved visual capacities in the absence of conscious visual experience. These preserved capacities include reflexive responses (e.g., pupillary reflexes), accurate localisation of visual targets using hand and eye movements, and shape and wavelength discrimination. Thus, for example, Weiskrantz (1986) found that the hemianopic patient DB could discriminate an X from an O in his blind field. Interestingly, however, patient DB was unable to perform more difficult discriminations between shapes in which neither the orientation of edges nor the overall area could be used as cues, implying some limit in the extent of unconscious visual processing.

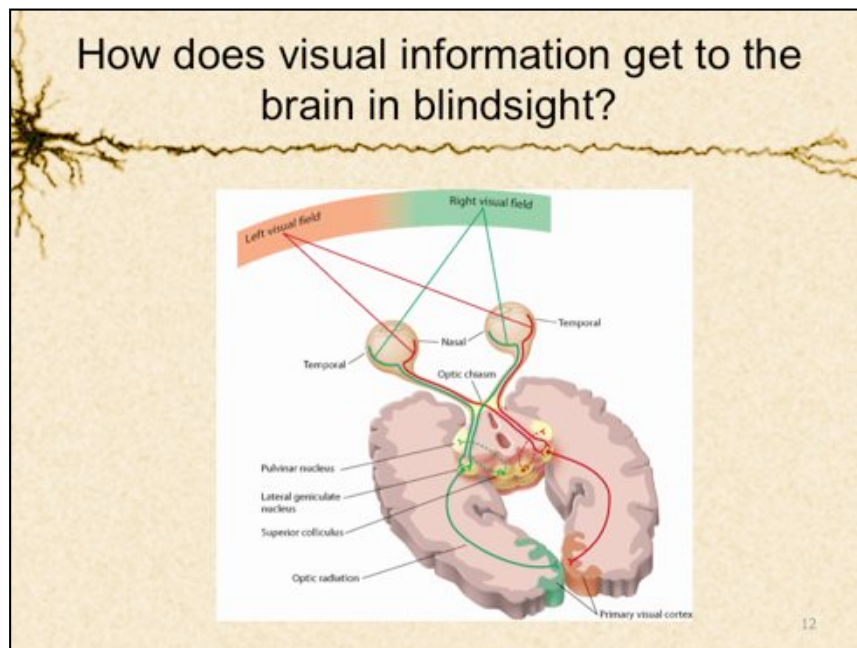
More recent studies have revealed that reaching, pointing and grasping to unseen targets may also be preserved to varying degrees in blindsight patients (e.g., Perenin & Rossetti, 1996).



In one experiment by Weiskrantz, patient DB was required to detect small spots of light flashed into various regions of his visual field. In the first part of the study, DB was asked to indicate when he saw the spots. He was unaware of visual stimuli that fell within a large region to the left of fixation (indicated in black in the figure; note that his damage involved the right visual cortex), but his reports of the same visual stimuli was normal in other parts of the visual field. In a second experiment, DB was shown the same spots of light at different positions within the 'blind' region of his visual field, but now he was required to **guess** whether a spot was present or absent on a given trial (on 50% of occasions a spot was presented, and on the remaining 50% there was no spot). Of course, the task seemed ridiculous to DB because he never consciously perceived the spots. Remarkably, though, DB was significantly above chance in detecting spots in his blind field, even though he reported having no conscious percept of them! When told of his performance DB was left speechless – how had he managed to detect visual stimuli he couldn't see?



In further experiments with another blindsight patient, GY (whose damage was in the left hemisphere), Weiskrantz examined whether spots of light presented in the blind field could be correctly localised by a simple pointing response. After a spot of light was flashed briefly either in GY's intact or blind hemifield, he was required to point to its location. Again the task seemed ridiculous to GY when the spot appeared in his blind field, because he had no conscious perception of visual stimuli in that region. Nevertheless, Weiskrantz found that GY's ability to localise spots was almost as accurate in his blind field as in his intact field. As with DB, GY was stunned by his ability to accurately locate visual stimuli he could not consciously see.



In order to explain the preserved visual abilities of blindsight patients, it is necessary to reconsider the anatomy of the visual pathways from the retina to the rest of the brain. (Go back and take a look at the notes from Lecture 7, in which we considered in detail the visual system.)

Recall that beyond the optic chiasm, axons in the optic tracts continue posteriorly until they form synapses with neurons in a part of the thalamus called the **lateral geniculate nucleus (LGN)**; there is one in each hemisphere). Neurons in the LGN send their axons posteriorly where they form synapses with neurons in the **primary visual cortex**. Note that about 90% of retinal axons course through the LGN on their way to the primary visual cortex, forming the so-called **geniculostriate pathway**. After damage to the primary visual cortex, these inputs are rendered ineffective, resulting in blindness.

But a further 10% of retinal axons bypass the LGN altogether, and project instead to the **superior colliculus (SC)**; part of the midbrain) and **pulvinar nucleus of the thalamus**, which in turn send axons on to other visual areas of the cortex. You will recall that the SC is involved in controlling the orienting response to sudden visual and auditory stimuli. It seems likely that activity in the SC, pulvinar, and the cortical regions to which they project, underlies the remarkable preservation of some visual capacities in blindsight patients. But note that without direct input from the LGN to primary visual cortex, there is no longer any **conscious visual experience**. Thus blindsight provides a striking example of a neuropsychological dissociation between conscious and unconscious perception.

## What is attention?

- Even in 'folk psychological' descriptions there seem to be several key aspects of attention:
  - selectivity (spatial, temporal, motoric)
  - capacity limitation
  - vigilance ( 'sustained attention' )
  - perceptual set ( 'expectation' )
  - switching

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We began the lecture by considering an example of how attention might play a role in determining which aspects of the visual world we are conscious of from one moment to the next. Before considering this issue further, we need to get a better idea of what we mean by the term 'attention'.

Attention may be **selective** in the sense that it restricts processing to just those aspects of the sensory input that occupy a particular region of space, or that occur at a particular time. For instance we may keep our attention focused on a particular face in a crowd, or on a perceptual input that corresponds to a specific point in time. But we seem unable to pay attention to everything at once, i.e., attention has a **limited capacity**. Thus we cannot simultaneously attend to every face in a crowd to check for a friend or acquaintance, despite our subjective impression of seeing everyone at once. In fact it turns out that we can attend to only around three or four separate objects at a time, and that attention must be redeployed elsewhere if we are to take in more information from a complex scene.

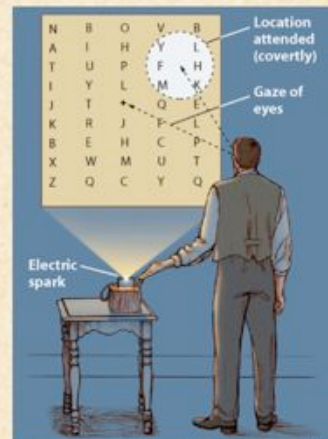
There also seems to be a limit in our **vigilance**, i.e., the period of time for which we can effectively sustain attention. Anyone who has had to monitor a display for the presence of rare, low salience events knows that it is difficult to sustain attention for more than a few minutes at a time without becoming fatigued and missing targets. This is one of the reasons radar operators and personnel on night-watch work in short bursts.

Attention is also involved in the establishment and maintenance of **expectations** or **perceptual set**. We tend to focus our processing resources on stimulus inputs and behaviours that are relevant to the current environment and task demands. Finally, attention is essential for flexible **switching** from one task to another, or from one environment to another. Without the ability to switch we would be forced to respond in a stereotypical fashion regardless of task demands or stimuli, an impairment that is sometimes apparent in neurological patients with frontal lobe damage.

In this lecture we shall restrict our consideration to the **selective** aspects of attention.

## Covert selective attention

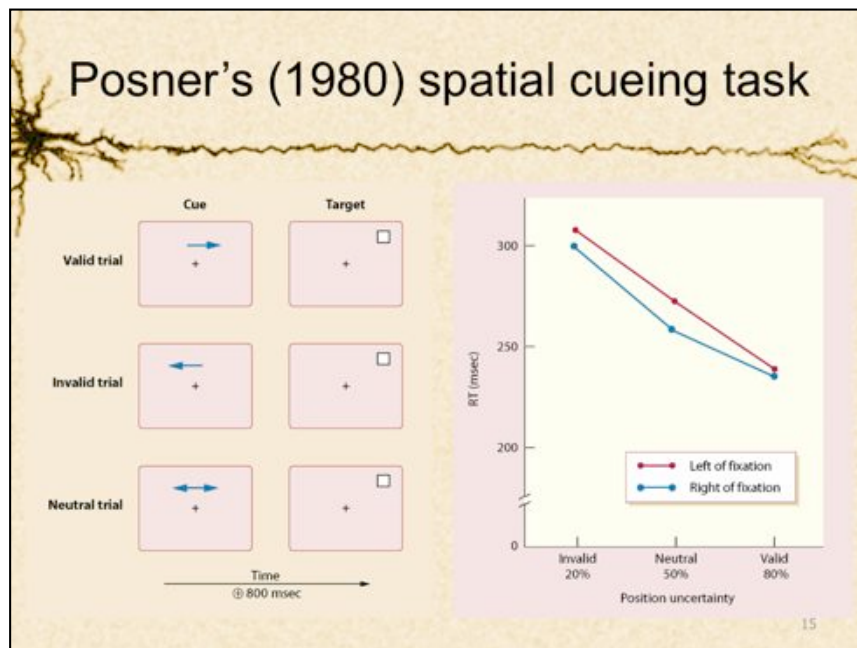
- Hermann von Helmholtz (1821-1894) - studied the effects of covert allocation of attention on visual perception
- *'one can concentrate attention on the sensation from a particular part of our peripheral nervous system and at the same time exclude attention from all other parts'*



One of the earliest experimental investigations of **selective attention** was performed by Hermann von Helmholtz (1821-1894). He wanted to determine how much visual information can be processed following brief glimpses; in so-doing he discovered an interesting phenomenon.

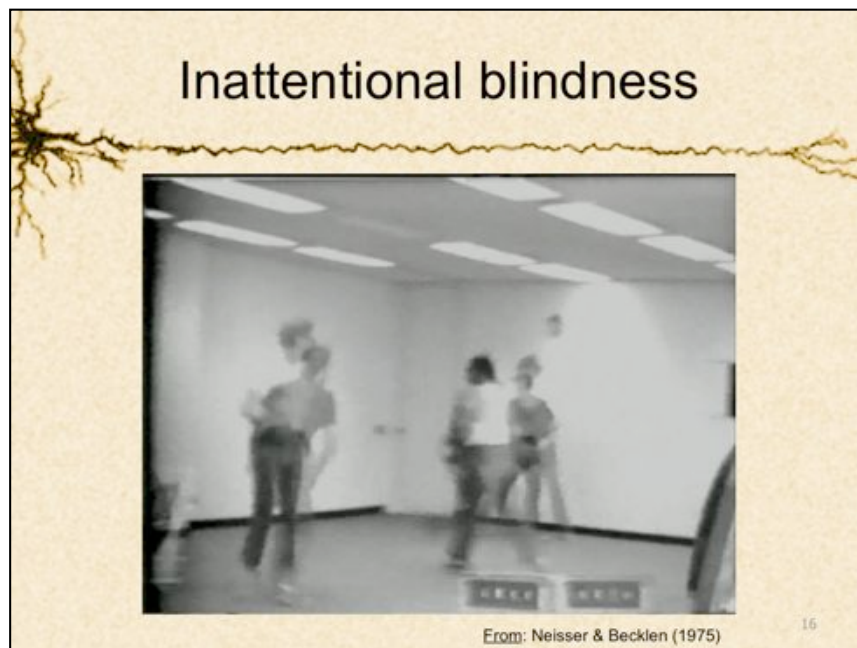
Helmholtz made a large screen in which letters were positioned at various distances from the centre. He then hung the screen on a wall of his laboratory, and excluded all light so that the entire lab was in complete darkness. Helmholtz then used a machine to create an electrical spark, which briefly illuminated the screen, much like a camera flash. Although there were far too many letters to see at any given moment in time, Helmholtz found that by keeping his eyes fixed on the centre of the screen he could pay attention to a selected region in advance (in other words, he attended **covertly** to a part of the screen, without actually moving his eyes to foveate it). He found that he was able to discriminate all the letters within the attended region, but was unable to do so for the rest of the letters on the screen.

By this simple experiment Helmholtz had demonstrated an important principle, namely, that voluntary allocation of attention can **enhance perception** of stimuli in a selected region of space, despite the receptors (in this case the retina) remaining fixed.



Almost 100 years after Helmholtz's pioneering work, Michael Posner developed a technique to quantify the effects of **spatial attention** on perception. In Posner's task, participants view a computer screen on which a small target is flashed briefly. Their task is to make a button-press response as quickly as possible when they detect the target. Thus the speed of response, or **reaction time (RT)**, is the dependent variable in this task. Shorter RTs are interpreted as reflecting more efficient processing, whereas longer RTs reflect slower processing. Posner manipulated spatial attention by presenting an arrow in the centre of the display just a few hundred milliseconds before the target appeared. The arrow could point left or right, or in both directions, and participants were informed that the direction of the arrow predicted the location of the subsequent target on 80% of trials (**valid trials**), but would indicate the opposite side on the remaining 20% (**invalid trials**). When the arrow pointed in both directions the target was equally likely to appear on either side (**neutral trials**). The basic rationale of this procedure is that the arrows can be used as **cues** that prompt participants to direct their attention covertly (without eye movements) to the left or right in anticipation of a target.

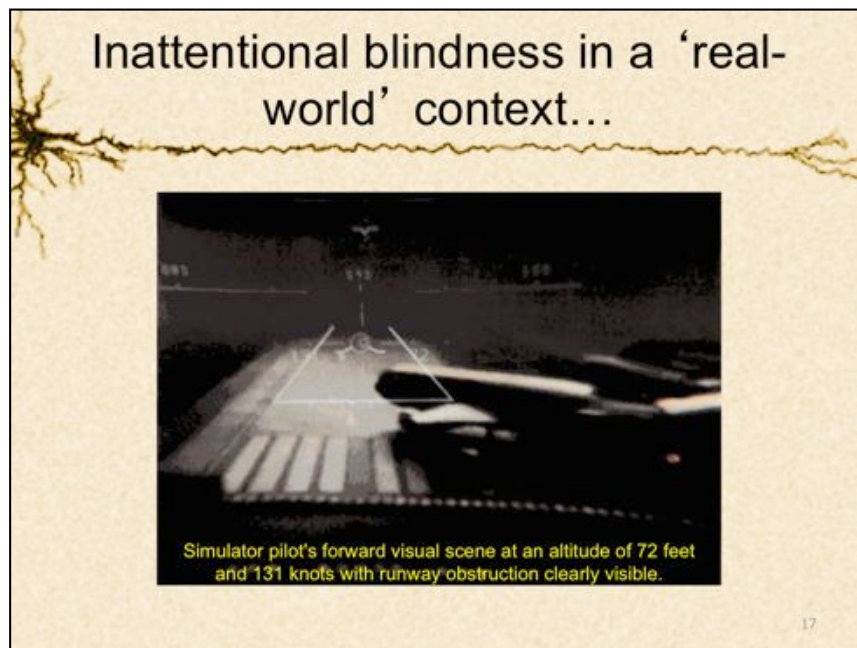
Consistent with the qualitative observations of Helmholtz, Posner found that participants were faster to respond to targets at validly cued than neutral or invalidly cued locations. These results have been interpreted as indicating that attention enhances the rate of information processing at attended relative to unattended locations, as reflected by the advantage for RTs to targets that appeared in locations to which participants had just had their attention cued by the arrow.



In the 1970s Ulric Neisser and his colleagues conducted a series of ingenious experiments designed to examine the effects of attention on **perceptual awareness**. In a classic demonstration, Neisser showed subjects a movie containing two superimposed sets of footage. The movie depicted two teams of three basketballers, one team wearing black shirts and the other wearing white. Each team passed a ball between themselves. The experimental participants' task was to count the number of passes made by one team or the other, ignoring the superimposed footage of the other team if possible. Performance on the ball-passing task was remarkably good, but Neisser found that participants could be 'blind' to unexpected stimuli, as this demonstration illustrates in a rather dramatic way.

Neisser and his colleagues replicated this apparent **inattention blindness** in various other forms, each time finding that subjects were remarkably insensitive to salient stimulus events when their attention was engaged elsewhere.





The early findings of Neisser and colleagues were forgotten by many psychologists, but in the late 1990s they attracted renewed interest as scientists began to consider the possible role of attention in modulating conscious perceptual experience.

Renewed interest in the findings also stemmed from the area of human factors, and in particular the study of human-operator accidents. It had been observed that apparently skilled operators would sometimes make inexplicable mistakes during routine tasks, often with disastrous consequences. For instance, Haines (1989) examined experienced pilots as they attempted to land a plane in a flight simulator. As they were landing, the pilots were monitoring a 'head-up' display of critical flight information that was projected onto the windscreen. Haines (1989) found that many pilots failed to notice that another aircraft had moved across the runway, thus blocking their path. Similar findings have emerged from road traffic accidents. Every year drivers crash their cars into parked vehicles or into trains at railway crossings, later claiming they did not see them. Thus the study of inattention blindness has compelling real-world implications, and provides important clues to the link between attention and awareness.



We have already seen that drivers and pilots miss salient perceptual events when they have their attention engaged on another task. But what happens when people are alerted to look out for something different or unusual?

Movie directors have long known that people are remarkably insensitive to errors of continuity in scene changes. Imagine the following scenario: during a movie you see a man put on a green overcoat, open the front door of his house, and step outside. Now cut to a view from outside the house as the man strides across the verandah and down some steps to a pathway. During the cut the man's green overcoat has changed to a blue denim jacket. Would you notice the change? Our intuition suggests that we would, but in fact such changes are rarely noticed.

Our apparent insensitivity to salient changes in visual scenes has been the focus of numerous recent investigations into the nature of selective attention, visual memory and perceptual awareness. It is now well established that observers fail to detect substantial changes in visual objects and scenes across saccades, eye blinks, movie cuts and even shifts of attention. This so-called **change blindness** is particularly interesting because it suggests there is a limit to the amount of visual information that can be encoded, maintained and compared across successive glimpses, contrary to our subjective impressions.

Change blindness occurs provided a **visual transient** is interposed between the original and changed images. This visual transient, which often takes the form of a blank screen, simulates the effect of a saccade. Similar effects have been achieved in other studies through the use of 'mudsplashes' (masking patches flashed briefly over the original image at the onset of a change); by using movie cuts; or by switching people or objects in real world situations. All these manipulations have the effect of capturing participants' attention during the critical change event, thus reducing the likelihood that the visual transient caused by the change itself will be noticed.

## Unilateral spatial neglect

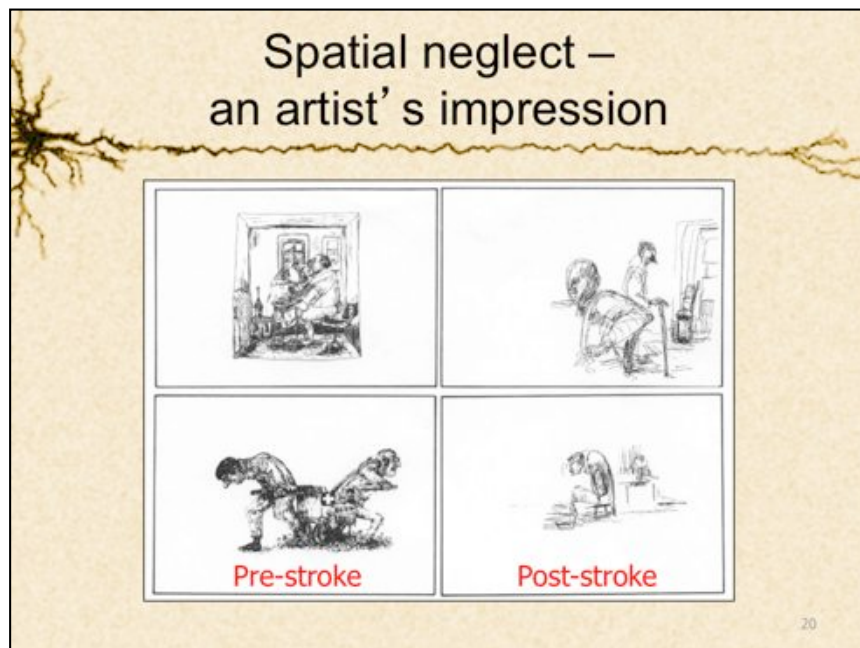
- Occurs after damage to one side of the brain (usually the right hemisphere)
- Patients behave as if the affected side of space (the *contralesional* side) has ceased to exist:
  - ignore food on one side of their plate
  - fail to shave or make-up one side of their face
  - bump into objects on one side
  - fail to read text from one side of the page
- Most common and severe after damage to the parietal lobe

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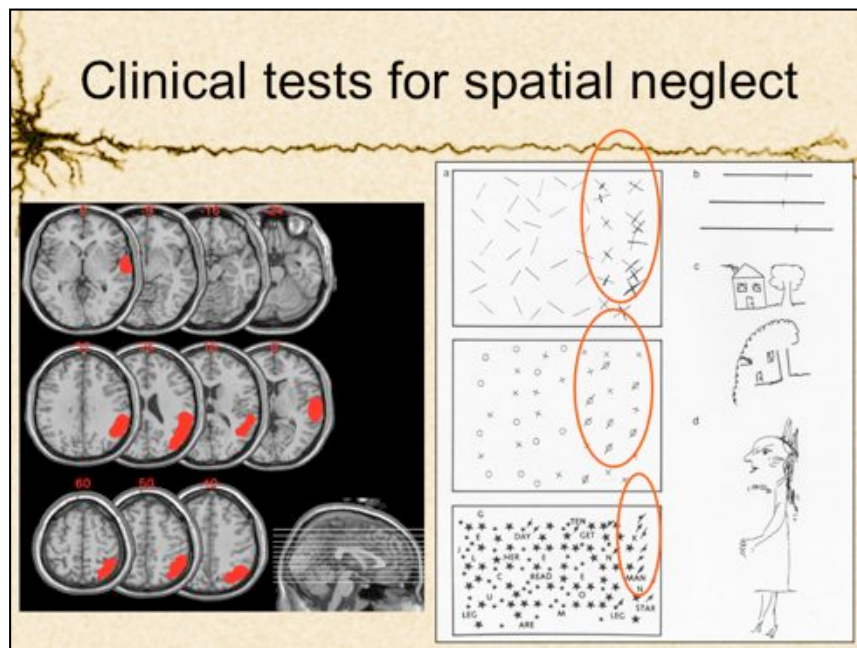
As indicated earlier, cases of blindsight suggest there is a dissociation between conscious and unconscious visual perception following damage to the primary visual cortex. It is perhaps not surprising that patients lose conscious vision after such lesions, given the crucial role played by this area in extracting edge and contour information during the initial stages of visual analysis (see Lecture 7). Damage at this early stage will clearly have catastrophic implications for visual processing carried out in other brain areas 'downstream'.

More astonishing are patients with **unilateral spatial neglect**, who are unaware of the **contralesional** side of space following unilateral damage, even though their primary visual cortex and many extrastriate areas remain completely intact. Patients with spatial neglect **behave as if one half of the world has simply ceased to exist**. Unlike hemianopic patients who are acutely aware of their blindness, and who usually develop strategies to actively compensate for it (e.g., by deviating their eyes and head toward the affected side to see more of what is in front of them), individuals with neglect have **no awareness** of their impairment and often behave as if nothing is wrong. Patients with neglect may fail to dress one side of their body, eat food from only one side of their plate, read words from one side of the page, and so on.

Spatial neglect can be observed after many forms of unilateral brain damage, but is most frequent and severe following lesions of the **parietal cortex of the right hemisphere**.



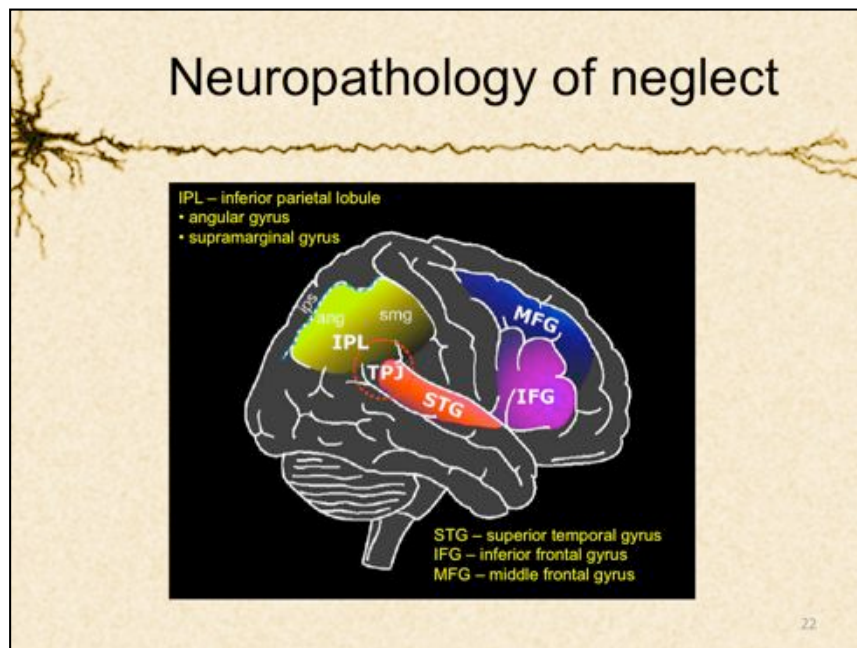
Neglect can manifest itself in many activities of daily living. Here is a striking example in a patient who was an artist, and who had suffered a stroke involving the right parietal lobe. Note that many details from the left (contralesional) side are missing in the post-stroke sketches.



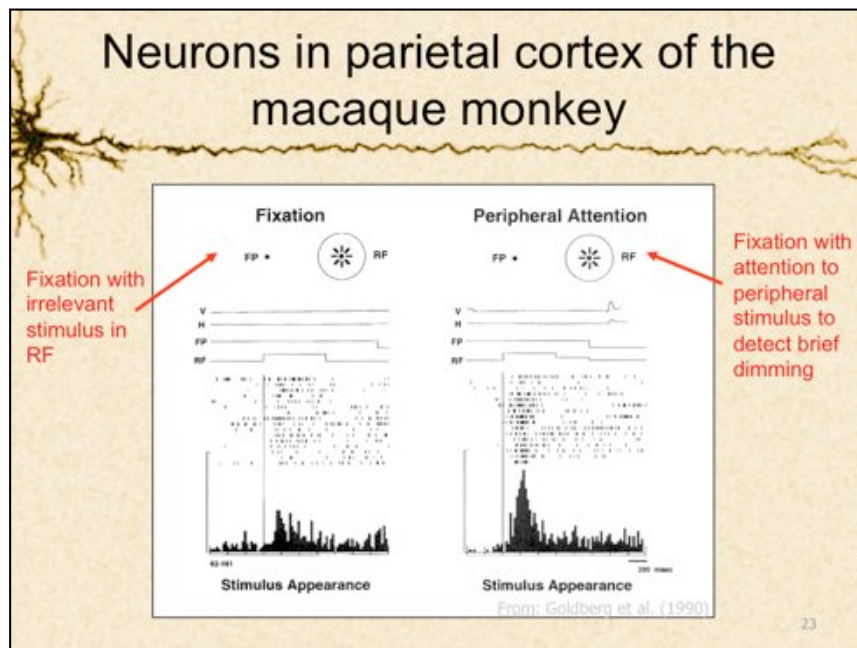
There are several clinical tests used to detect the presence of neglect. These examples come from a patient with a lesion of the right parietal lobe, as illustrated in the panel on the left which shows areas of damage in red drawn onto horizontal slices of a normal brain obtained using MRI (see Lecture 6 for details on MRI and other brain imaging techniques).

The patient fails to locate left-sided visual targets scattered on an A4 page (targets are lines in the top panel, circles in the middle panel and small stars in the lower panel). When asked to indicate the midpoint of horizontal lines, she places her mark too far to the right, as if the left end of the line has not been seen. There are also anomalies and omissions on the left side in copying of familiar objects and in spontaneous drawing.

What is particularly striking about neglect is that when patients have their attention drawn to their omissions, they seem to regain some partial and transient consciousness for that part of the world they were oblivious to a moment before. In this example, when the patient's attention was drawn to the left during the clinical tests she managed to locate more left-sided targets during cancellation, and bisected lines much closer to their true midpoint. The profound loss of conscious perception in spatial neglect reflects a **failure of mechanisms of attention** that normally select stimulus inputs from the contralesional side of space.



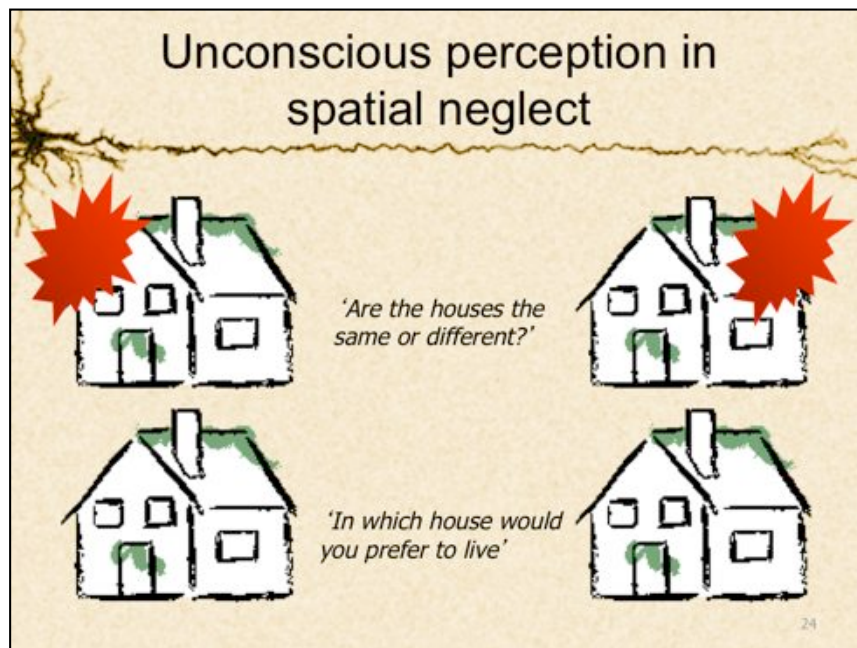
Spatial neglect is most frequently encountered in patients with stroke-induced lesions of the right hemisphere, particularly when the damage involves the **inferior parietal lobule (IPL)**. There are several other brain areas, damage to which has been implicated in neglect; these are the superior temporal gyrus (STG), the inferior frontal gyrus (IFG), and the middle frontal gyrus (MFG).



Extracellular microelectrode recordings in macaque monkeys have shown that single neurons in monkey parietal cortex modulate their rate of firing in accordance with the attentional demands of a visual task. Some of the pioneering research in this area has been conducted by Michael Goldberg and his colleagues.

In one study Goldberg et al. began by mapping the receptive field of individual neurons as the monkey fixated a central spot on a computer display (**left panel** in the figure). When a stimulus was flashed briefly in their receptive field these parietal cells showed a small increase in their rate of firing. In the second part of the study, the authors trained the monkeys to release a lever whenever they detected a brief dimming of the same stimulus. Now the neurons fired much more vigorously (**right panel** of figure), indicating that their response to visual stimulation was increased when the monkey directed its attention (covertly) to the stimulus within the receptive field. Thus, rather than giving a uniform response to all visual stimuli presented within their receptive fields, **parietal neurons change their rate of firing according to the attentional demands of the task**. Many subsequent studies have replicated and extended these findings.

To the extent that parietal areas in monkeys correspond roughly with those in humans, these single-unit recordings provide some explanation for why patients with neglect fail to attend to the contralesional side of space. If parietal neurons modulate their activity based on attentional demands, then damage to these cells might lead to pathological **inattention** for visual stimuli on one side of space.



Despite neglect patients' profound loss of conscious perception for stimuli arising on the contralesional side of space, there may nevertheless be considerable **unconscious processing** of neglected information.

In one study, a patient with left neglect was asked to judge whether two houses in a vertically aligned pair were the same or different. In each pair, one of the two houses had flames emerging from either the right or left side. When the flames were on the right, the patient always said 'DIFFERENT' and pointed to the flames; by contrast, when the flames were on the left the patient invariably said 'SAME', because she neglected the left side of the stimuli (and the houses were the same on their right side).

After performing this test, the patient was asked a second question: 'If you had to choose, in which house would you prefer to live?' For trials in which the flames were on the right the patient always indicated the house without the flames as the one in which she would prefer to live, saying she wouldn't want to live in a house that was burning down! Crucially, when asked the same question for stimulus pairs in which she had neglected the left-sided flames, the patient continued to reliably choose the house without the flames, although she complained that the question was silly because the houses were of course 'identical'.

These findings suggest that despite the absence of conscious perception in neglect, such patients may nevertheless process some aspects of the neglected stimulus unconsciously. Such unconscious perception is likely to be subserved by neural pathways that extend from the primary visual cortex (which remains intact in most neglect patients) into the **object recognition pathways** of the temporal lobe. Damage to the parietal cortex impairs selective attention, and so patients remain unaware of perceptual inputs on their affected side; but the object recognition pathways continue to function normally, processing object identity without the patient's **explicit knowledge**.



## Summary

- Blindsight - behavioural evidence and neural bases
- Selective attention – definitions, procedures for measuring spatial selection
- Normal limits of conscious perception – inattentional blindness, change blindness
- Unilateral spatial neglect – behavioural effects, neuropathology, unconscious processing