

Chapter 4: Perception, motion and action

The first major theme addressed in this chapter is perception for action, or how we manage to act appropriately on the environment and the objects within it. Of some relevance here are theories (e.g., the perception–action model and the dual-process approach) that distinguish between processes and systems involved in perception-for-recognition and those involved in perception-for-action. There is convincing evidence that attention plays an important role in determining which aspects of the environment are consciously perceived.

- **Direct perception**

In the past it was assumed that the function of visual perception was object identification. Gibson’s radical idea (e.g., 1950) was that perceptual information is used primarily in the organisation of action, facilitating interactions between the individual and his/her environment. According to Gibson, perception influences our actions with minimal involvement of conscious awareness.

WEBLINK: [Gibson’s theory](#)

Gibson regarded his theoretical approach as “ecological”. He proposed that perception involves picking up information directly from the optic array – the structured pattern of light striking the eye, containing unambiguous information about objects in the environment. The optic flow consists of changes in the pattern of light reaching an observer created when he/she moves, or parts of the visual environment move.

According to Gibson, optic flow provides pilots with unambiguous information about their direction, speed and altitude:

- The point towards which the pilot is moving (the focus of expansion) appears motionless, while the visual environment appears to be moving away.
- Texture gradients – the gradient of texture density from slanting objects – also provides very useful information.

Optic flow was important for goal-directed walking. Gibson (1966, 1979) argued that certain higher-order characteristics of the visual array (invariants) remain unaltered when observers move around their environment. These include the focus of expansion and the horizon ratio relation.

WEBLINK: [Detail about optic flow](#)

Gibson (1979) claimed that all potential uses of objects (their affordances) are directly perceivable (e.g., a chair “affords” sitting). Most objects give rise to more than one affordance. The affordance that affects behaviour depends on the perceiver’s current psychological state. According to Gibson, visual input contains all the information required to learn about which affordances will satisfy particular goals. Di Stasi and Guardini (2007) found that observers’ judgements of the affordance of “climbability” of steps matched the amount of energy they would spend actually climbing them. [Pappas and Mack \(2008\)](#) found that an object’s affordances may not be consciously perceived, yet still produce motor priming.

CASE STUDY: [Gibson’s theory of direct perception affordances](#)

The ecological approach has proved successful in some ways. Gibson was right to emphasise the following:

- An important role of visual perception is in guiding movement around our environment.

- Our perceptual system allows a rapid response to the environment without making use of memory – a vision-for-action system.
- Visual input provides much more information than had previously been thought, particularly from motion.

Limitations of Gibson's approach include:

- oversimplification of the processes in perception;
- Gibson virtually ignored the vision-for-perception system;
- Gibson's argument that we do not need to assume the existence of internal representations to understand perception is flawed.

Gibson argued that perception and action are closely intertwined, with the main purpose of visual perception being to assist in the organisation of action. According to his direct theory, movement of an observer creates optic flow, which provides useful information. Gibson also claimed that the uses of objects (their affordances) are perceived directly and detected by a process of resonance. Gibson's approach was very forward-thinking and focused on important interactions between vision and action that had previously been ignored. However, he underestimated the complexity of visual processing, and de-emphasised those aspects of visual perception concerned with object recognition.

- **Visually guided action**

When someone is moving forwards, the point towards which he/she is looking appears motionless while the visual field around that point seems to expand. Gibson proposed a global radial outflow hypothesis, which states that the overall or global outflow pattern specifies an observer's heading. Gibson's views are ingenious – however, complications occur when we consider what happens when we cannot move directly to the goal. Typically, the retinal flow field is determined by linear flow, containing a focus of expansion, and rotary flow, produced by a curved path and eye/head movements. Extra-retinal information about eye and head movements may be used to remove the effects of rotary flow.

WEBLINK: [Optic flow and heading demonstrations](#)

Brain areas such as the medial superior temporal cortex and ventral intraparietal cortex are implicated in processing optic-flow and heading information. [Wilkie and Wann \(2003\)](#) found that steering on a simulated driving task was affected by extra-retinal information. [Van den Berg and Brenner \(1994\)](#) pointed out that we only need one eye to use optic-flow information, yet heading judgements are more accurate with two eyes. [Hahn et al. \(2003\)](#) provided evidence that motion is not essential for accurate perception of heading, as subjects could make direction judgements from static photos. Visual direction (the angle between a target and the front-back body axis) is used as a cue when we walk directly to a target. [Wilkie and Wann \(2002\)](#) used a simulated driving task and found that visual direction, extra-retinal information and retinal flow were all used in steering.

When moving along a curved path, path judgements (identifying future points along the path) may be more important than judgements of heading. [Wilkie and Wann \(2006\)](#) found that, when travelling along curved paths, observers made fewer errors on path judgements than on heading judgements. Separate processes may underlie heading and path judgements. Drivers approaching a bend tend to look ahead some distance. Drivers approaching a bend may focus on the tangent point – the point at which the direction of the inside of the road appears to reverse (Wilkie et al., 2010). However, road curvature can be estimated accurately without fixating on the tangent point (Mars & Navarro, 2012).

Gibson's views on the importance of optic-flow information are oversimplified. Numerous other factors can influence visually guided movement such as extra-retinal information, relative depth of objects, visual direction, retinal flow and future path information. Research has been limited in addressing how individuals decide on which information to use while on the move and the role of learning has been under-researched.

When we are moving towards an object, or when one is moving towards us, we often want to know when we are going to reach it. We can calculate time to contact by estimating distance and speed, but this is complicated. [Lee \(1976\)](#) argued that this calculation is unnecessary if we (or the object) are moving with constant velocity. In this case:

- The time to contact (τ) is specified by the size of the object's retinal image divided by its rate of expansion.
- The rate of decline of τ over time ($\dot{\tau}$) indicates whether there is sufficient braking.

[Tresilian \(1999\)](#) identified four limitations of τ :

- τ ignores acceleration.
- τ only provides information about time to contact with our eyes, and not, for example, the front of the car.
- τ is only accurate if objects are spherically symmetrical.
- τ requires that image size and expansion of the object are both detectable.

Tresilian argued that time to contact is actually determined by combining information from several different cues.

According to Gibson, our perception of heading depends on optic-flow information. However, his view was an oversimplification since the retinal flow field is determined by eye and head movements as well as by our movement through the environment. Heading judgements are also influenced by visual direction and binocular disparity. When moving along a curved path, path judgements may be more important than heading judgements. According to the τ hypothesis, observers assume that moving objects have constant velocity, and they use τ to estimate time to contact. While there is some evidence for this view, time-to-contact estimation also depends on information from binocular disparity and knowledge about familiar size and gravity. Time-to-contact estimates typically depend on combining information from various sources.

- **Planning-control model**

[Glover \(2004\)](#) looked at how visual information is used in the production of action. He argued for an initial planning system followed by a control system with some temporal overlap. Key characteristics of the planning system are:

- It is used mostly before initiation of movement.
- Functions include selecting a target, and deciding how and when to grasp.
- It is influenced by factors including goal and context.
- It is relatively slow and involves conscious processes.
- It depends on a visual representation in the inferior parietal lobe and motor processes in frontal lobes and basal ganglia.

Key characteristics of the control system are:

- It operates during movement.
- It ensures movements are accurate.

- It is influenced only by the target's spatial characteristics, not by context.
- It is relatively fast and does not involve conscious processes.
- It depends on a visual representation in the superior parietal lobe and motor processes in the cerebellum.

Most errors and inaccuracies in perception and action stem from the planning system. Visual illusions occur because of surrounding visual context. This information is used by the planning system but not by the control system. Glover's planning–control model is similar to Milner and Goodale's theory of two visual systems, but includes more detail on planning processes and specifies brain areas underlying planning and control.

According to the model, initial actions towards an object are determined by the planning system. Subsequent actions are influenced by the control system.

- If visual illusions mainly affect the planning system, illusory effects should be stronger for initial actions than for subsequent actions.
- [Glover and Dixon \(2001\)](#) found that, in the Ebbinghaus illusion, illusory effects on hand orientation were large early on but disappeared as the hand approached the bar.

According to the model, action planning involves slower conscious processing. Action control involves rapid, non-conscious processing. A secondary task that involves conscious processing should interfere with action planning but not action control. [Glover and Dixon \(2001\)](#) found that a word label ("LARGE" or "SMALL") affected participants' grip aperture early in their reach, but its influence decreased later.

According to the model, visual context influences the planning system but not the control system. [Mendoza et al. \(2006\)](#) found that presenting additional arrowheads in the Müller–Lyer illusion affected participants' behaviour irrespective of whether they were presented during planning or control stages of movement.

Findings from brain imaging provide some support for the prediction that planning involves the inferior parietal lobe, whereas control involves the superior parietal lobe. TMS to the area bordering the inferior and superior parietal lobes resulted in interference with control rather than planning. Striemer et al. (2011) accepted the inferior parietal lobe may be required for some functions of the planning process (e.g., selecting the goal of the action, selecting the target for the action). However, their findings suggested it is *not* involved in detailed action programming. Damage to the left inferior parietal lobe often produces ideomotor apraxia in which patients find it hard to carry out learned movements. Patients with ideomotor apraxia were substantially poorer at planning their actions when blindfolded and their performance was associated with damage to the inferior parietal lobe. Damage to superior parietal lobe often produces optic ataxia – impairment in the ability to make accurate movements in spite of intact visual perception.

There is support for the notion that cognitive processes are involved in the planning of actions. There is evidence that different processes are involved in online control of action and in action planning. TMS studies have provided evidence that areas in the inferior and superior parietal cortex are important for planning and control, respectively. However, planning and control systems undoubtedly interact in complex ways and the sequence of planning and control may not be linear. Also, the model is concerned primarily with body movements rather than eye movements. Eye–body coordination is important for precise movement.

INTERACTIVE EXERCISE: [Planning and control](#)

In Glover's planning-control model, he distinguished between a slow planning system used mostly before the initiation of movement and a fast control system used during the carrying out of a movement. According to the model, action planning involves conscious processing and depends on a visual representation in the inferior parietal lobe. Action control involves non-conscious processing and depends on the superior parietal lobe. As predicted by the model, action errors typically stem from the planning system rather than the control system. Evidence from brain-damaged patients and from brain imaging in normals supports the proposed locations of the planning and control systems. The processes of the planning system need to be spelled out in more detail, as do the complex interactions between the two systems.

- **Perception of human motion**

People are very good at interpreting biological motion. Johansson (1975) attached lights to actors' joints so that only the lights were visible in the dark. He found that observers could make very good judgements about movement and posture. Biological motion could be perceived when a point-light display was shown for just 0.2s ([Johansson et al., 1980](#)). Observers can also discriminate the gender of a walker from point-light displays. Structural cues (e.g., width of shoulders and hips) and dynamic cues (sway of upper body vs. hips) are used to judge the gender of a walker.

WEBLINK: [A good demonstration of biological motion perception](#)

WEBLINK: [A fantastic simulation of biological motion. You can alter features to see how your perception changes](#)

WEBLINK: [Another biological motion simulation site, but this time with people engaging in different activities](#)

Johansson (1975) argued that the ability to perceive biological motion is innate. [Simion et al. \(2008\)](#) found that newborns preferred to look at a display showing biological motion (moving chickens), and looked longer at upright displays than inverted ones. These findings support the notion that perception of biological motion involves simple bottom-up processes. However, [Thornton et al. \(2002\)](#) provided evidence that top-down processes can be important for detection of biological motion. When a point-light display was masked by either a scrambled mask or a random mask, observers found it harder to identify the walker's direction in the scrambled mask condition.

WEBLINK: [Johansson: Motion perception part 1](#)

Different areas in the brain may be involved in perceiving biological motion and in perceiving general object motion:

- "Motion-blind" patients with an impaired ability to perceive general motion have damage to motion areas MT and MST.
- In contrast, stroke patients with impaired perception of biological motion have lesions in the superior temporal and premotor frontal areas.
- The posterior superior temporal gyrus and sulcus are consistently activated during observation of point-light displays but biological motion selectively activates an area in the superior temporal sulcus.
- However, although there are specific differences, overall brain activation patterns are highly similar for perception of biological motion and object motion.

Our ability to perceive biological motion may be based on imitation. [Gallese et al. \(2004\)](#) demonstrated the existence of "mirror neurons" in area F5 of the monkey premotor cortex. These neurons were activated

both when the monkeys were performing an action (e.g., grasping) and when they observed another monkey performing a similar action. It has been proposed that the mirror neuron system facilitates imitation and understanding of others' actions and intentions. In monkeys, area F5 and the superior temporal sulcus form part of the mirror neuron system. [Umiltà et al. \(2001\)](#) showed that monkey mirror neurons discharged as strongly when the experimenter's reaching action was visible to the monkey, and when the action was hidden behind a screen but the monkeys were aware that the experimenter was reaching for food.

In humans, there is only limited evidence for the existence of a mirror neuron system. [Iacoboni et al. \(2005\)](#) showed that the brain areas forming part of the mirror neuron system were more active when there was a context that helped explain the intention of the action being viewed. However, there are currently no studies demonstrating that the same *neurons* are activated whether observing a movement or performing it.

WEBLINK: [Mirror neuron system](#)

Our ability to perceive biological motion may depend on a combination of bottom-up and top-down processes. However, we know little about how bottom-up and top-down processes interact. The brain areas involved in perception of biological motion may differ from those involved in general motion perception. However, the exact nature of these differences is unclear. The mirror neuron system is involved in helping us to understand others' movements. However, there is still no direct evidence for a human mirror neuron system at the level of the individual neurons.

Biological motion is perceived even when visual information is impoverished (e.g., point-light displays). The perception of biological motion is likely to involve both top-down and bottom-up processes. Different brain areas may be involved in detecting biological motion (e.g., superior temporal sulcus; VP) and detecting motion in general (area MT). The mirror neuron system in monkeys is activated when the animal performs an action and when it observes another animal performing the same action. It is thought that this system is involved in imitation and in understanding the intentions of others' actions. However, in humans, evidence for a similar mirror neuron system is weak.

- **Change blindness**

WEBLINK: [A demonstration of change blindness](#)

WEBLINK: [More demonstrations of change blindness](#)

WEBLINK: [A demonstration of inattentional blindness](#)

Our ability to detect change in the visual environment is often far less impressive than we think it is. The phenomenon in which observers do not notice an unexpected object appearing in the visual display is inattentional blindness, which is closely related to change blindness, a failure to detect that an object has moved or disappeared.

- Change blindness involves dynamic processes in visual perception applied to two or more stimuli.
- Experiments on change blindness have shed light on the role of attention in scene perception.
- Most magic tricks involve misdirection, capitalising on the phenomenon of change blindness.

[Levin et al. \(2002\)](#) found that participants watching a video of two people having a conversation in a restaurant did not notice when the plates changed colour or when a scarf disappeared. [Simons and Chabris \(1999\)](#) demonstrated inattentional blindness when observers watching a film did not notice a woman in a

gorilla suit walking on to the screen even though she was on screen for nine seconds! In the real world, motion signals typically accompany changes in the visual environment.

WEBLINK: [Gorillas in the midst](#)

In early research, change blindness was explained by limited attentional focus resulting in sparse and incomplete visual representations of a scene. However, this is probably an oversimplification. [Simons and Rensink \(2005\)](#) proposed alternative explanations:

- Detailed representations decay rapidly or are overwritten.
- Visual representations are inaccessible to consciousness.
- Pre- and post-change visual representations are not compared.

WEBLINK: [Magical videos](#)

Attentional processes play an important role in change blindness. Unexpected stimuli that are similar to target stimuli are more likely to attract attention and be detected more often than those that are dissimilar. Hollingworth and Henderson (2002) found change detection was much greater when the changed object had been fixated before the change.

- There was no real evidence that observers could accurately detect changes in objects not fixated prior to change, which suggests that attention to the to-be-changed object is necessary (but not sufficient) for change detection.
- The number of fixations on other objects after the to-be-changed object had no effect on change detection. Hence visual representations of attended objects last for some time after they are formed.

[Triesch et al. \(2003\)](#) argued that we typically focus only on information that is directly relevant to the current task.

- Inattention blindness and change blindness are important phenomena.
- Prior attention is necessary but often not sufficient for change detection.
- We form detailed visual representations of stimuli, but much of the detail becomes inaccessible unless attention is directed to it.
- Changes not detected at the conscious level can nevertheless influence cognitive processing and behaviour.

There is convincing evidence for the existence of inattention blindness and change blindness. The percentage of observers showing these effects depends on several factors, including the observer's intention, the sensitivity of measurement, the similarity between the unexpected object and attended objects (inattention blindness), and the extent of change (change blindness). However, the single most important factor in change blindness is whether the changed object was attended to prior to change. Reasonably detailed representations of attended parts of a visual display are formed, but this detail is inaccessible unless attention is directed to it. Nevertheless, even visual changes not consciously detected can have effects on cognitive processing and behaviour.

Additional references

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