OPNs

►Omnipause Neurons

Opsin Evolution

►Evolution of Eyes

Opsonin

Definition

A terminology derived from the Greek and meaning, sauce or seasoning, in other words making the target cells such as pathogen more palatable to the phagocyte and more easily eaten. For example, C3b is an opsonin bound to target cells following complement activation and promoting phagocytosis by macrophages expressing C3 receptors.

►Neurodegeneration and Neuroprotection – Innate Immune Response

Optic Ataxia

Definition

Specific impairment of the visual control of limb movements observed in patients with lesion of the posterior parietal cortex. This deficit is expressed as errors both in final limb position in reaching/pointing tasks and in the shaping of hand aperture in grasping tasks. These deficits are exacerbated when the movements are programmed and executed under peripheral vision by asking the patient to keep gaze on a fixation point. Pure forms of optic ataxia, without sensory or motor deficits, indicate a role of the posterior parietal cortex in visuo-motor transformations for limb movement control.

►Eye-Hand Coordination
►Visual Neurosychology
►Visual Space Representation for Reaching

Optic Axis

Definition

Where we look, i.e., roughly coincidental with the line of sight.

Optic Chiasm

Definition

The optic chiasm is a landmark between the optic nerve and optic tract in the pathway between the retina and lateral geniculate nucleus of the thalamus. It contains the crossing of fibers of the so-called optic nerve to form its continuation, the optic tract of the opposite side. The fibers arise from ganglion cells in the retina. The crossing fibers in the optic chiasm contain information from the temporal visual fields (retinal nasal fields) of both eyes. Uncrossed fibers in the optic chiasm contain information from the nasal visual fields (temporal retinal fields) of both eyes. The chiasm is located on the ventral surface of the brain at the level of the anterior hypothalamus.

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Optic Flow

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Synonyms

Optical flow; (optic) Flow field; Retinal flow

Definition

Optic flow is the pattern of motion induced on the retina of a moving observer.

Characteristics

Mathematical Properties

Optic flow arises from the movement of an observer through a static visual scene. The movement of the observer creates relative movement between the visual objects in the scene and the eye of the observer. The projection of the relative movement of the scene objects onto the ►visual field of the observer creates ►visual motion. The collection of all the visual motions from throughout the visual field forms the optic flow. Since the motion in the visual field is first sensed by its projection on the retina, retinal flow is the collection of all image motion on the retina that arises from observer movement.

The retinal projection of the relative movement of a point in the scene can be described as a motion *vector*, i.e., by noting the motion direction and speed on the retina. The direction depends on the particular self-motion that the observer performs. When the observer moves to the left, all image motion is directed to the right. When the observer moves straight forward, all image motion is directed radially away from a point in the movement direction of the observer. This point is known as the ►focus of expansion. The speed of a particular motion vector in the optic flow depends on the distance of the point from the eye of the observer. Points near to the observer move faster in the retinal projection than points further away. The difference in the speeds of two points in the same visual direction but in different distances from the observer is known as ►motion parallax.

Optic flow not only arises from linear translations of the observer, such as sideward or forward movement, but also from rotations. Such rotations can occur either from moving along a curve or from eye movements of the observer. For example, when the observer performs an eye movement from right to left then rightward visual motion is induced on the retina. However, unlike in the case of leftward linear translation, the speeds of the motion vectors induced by eye rotation do not depend on the distance of the respective scene points from the observer. All points move with the same speed which is exactly opposite to the speed of the eye movement.

Thus, a single optic flow vector θ of a point R in the scene is mathematically a function of the translation T and rotation Ω of the eye of the observer and the distance Z of the point from the eye: $\theta = f(T, \Omega, Z)$. The precise equation is derived from perspective geometry [1]. Important for many aspect of flow analysis is the fact that in this equation the observer speed T and the depth Z are coupled such that the flow depends only on the quotient T/Z, not on Z directly.

The simplest optic flow is that of the radial outward movement obtained from linear forward movement. However, this is only a special case and the combination of translation, rotation, and scene distances can give rise to very different optic flow patterns. Since observer movement naturally triggers gaze stabilization reflexes such as the ►vestibulo-ocular reflex or the ►optokinetic reflex the optic flow observed under natural conditions will often result from a combination of translation and eye rotation.

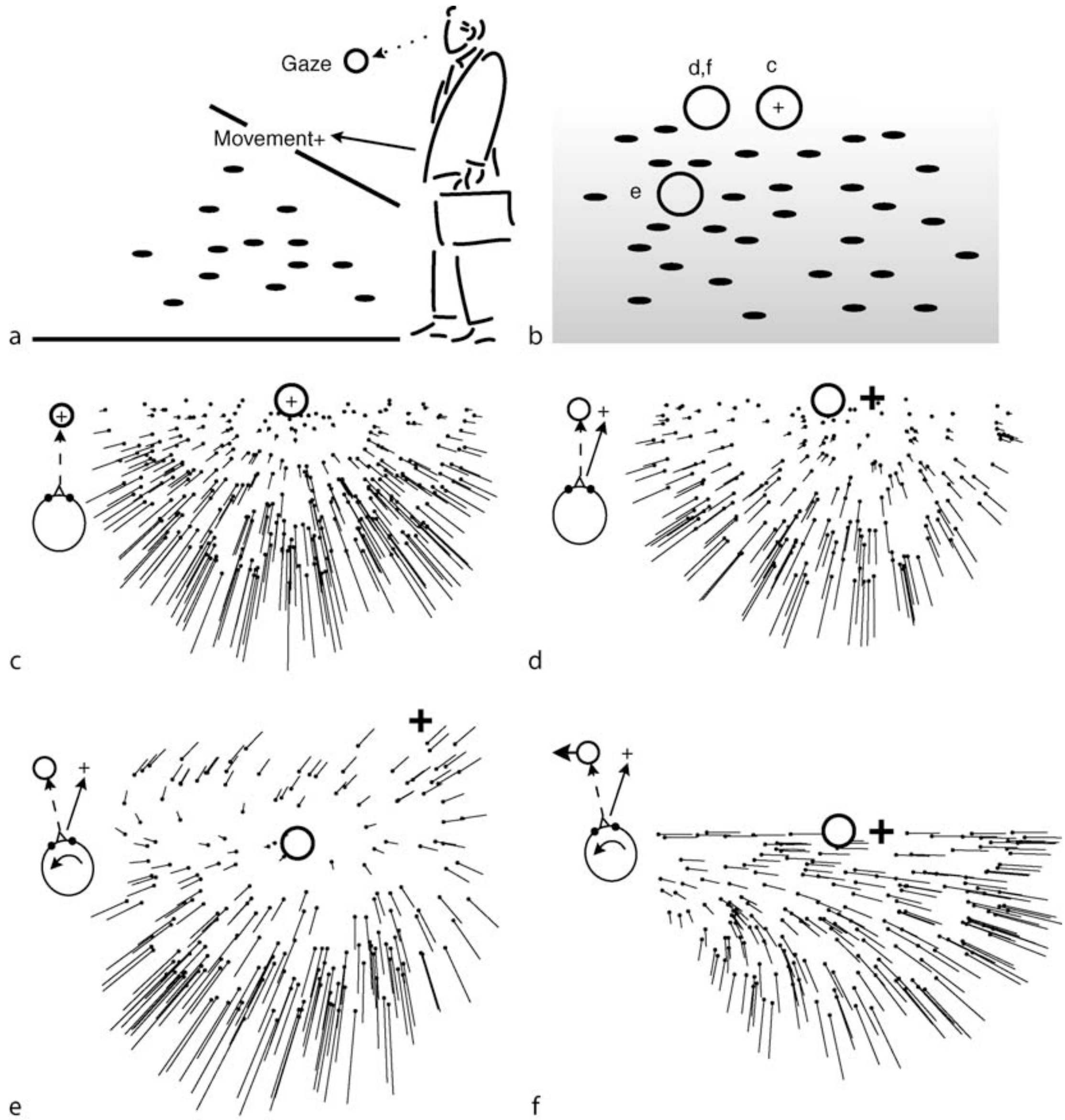
Figure 1 shows a few characteristic examples. The observer moves across a ground plane. Heading is marked by a cross, gaze direction by a circle. Panels c to f show cases where the same heading is combined with different gaze directions. These gaze directions are shown in panel b. Panel c shows the retinal flow when gaze coincides with heading, i.e., when the observer looks straight into the direction of movement. In this case a focus of expansion is centered on the retina. In panel d, the observer looks off to the side. Gazing at some fixed point on the horizon allows him to keep his eyes stationary, i.e., no eye movements occur. A focus of expansion identifies heading, but now it is displaced from the center of the visual field. In panel e, the observer's gaze is directed at some element of the ground located in front of him and to the right. Because gaze is directed downward the horizon is in the upper visual field. Moreover, since the observer now looks at a point that is moving relative to himself, an eye movement is induced to stabilize gaze on this point. The resulting retinal flow field, a combination of translational and rotational flow, resembles a distorted spiraling motion around the fovea. There is no focus of expansion in the direction of heading (+). In panel f the observer looks at the same point as in panel d, but now he tracks an object that moves leftward along the horizon (for instance a car). This leftward pursuit induces rightward retinal image motion. The combination with the forward movement results in a motion pattern that resembles a curved movement and does not contain a focus of expansion.

Behavioral Aspects

From its conception by Gibson in the 1950s [3] optic flow has been assumed to play a role in the control of self-motion. Since then, experimental studies have shown that optic flow is involved in many behavioral tasks:

Control of Stance. Direction and speed of the optic flow are used as feedback signals for postural stability. When standing observers are exposed to a large flow field that periodically expands and contracts they sway in phase with the flow field [4]. The coupling between optic flow and posture maintenance is particularly strong in children and decreases in strength with age as the influence of ►vestibular and somatosensory contributions to postural stability increases.

Control of Speed. Walking observers use the speed of the optic flow as a control signal for walking speed. Normally, a particular forward movement leads to a particular optic flow speed. If the flow speed is artificially increased, as has been done for observers walking on a treadmill in front of a projection screen on which a flow pattern was presented, walking speed increased proportionally [5]. Similar effects are seen for bicycling and car driving. When a mismatch between flow speed and walking speed is maintained for a



Optic Flow. Figure 1 Examples of optic flow fields induced by combinations of forward movement and eye movement. Taken with modifications from [2]. See text for detailed explanation. (a) Observer moves towards the cross while lookins at the circle. (b) different directions of gaze used in panels c to f. (c) Optic flow for straight translation int the direction of gaze. (d) Optic flow when directon of motion differs from direction of gaze. (e) Optic flow when direction of motion differs from direction of gaze and gaze stabilizing eye movement reflexes are taken into account. (f) Optic flow when direction of motion differs from direction of gaze and the observer tracks a moving object.

several minutes, for example when the flow speed is constantly lower than normal for a runner on a treadmill, an after effect is observed in which the walker inadvertently advances when attempting to run in place on solid ground with eyes closed.

3D Scene Perception. Because of motion parallax the optic flow contains information about the distances of the points of the scene. This information can be extracted to estimate the relative distances between objects in the scene and to recover surface layout [1]. Absolute distances cannot be retrieved from the optic flow because flow magnitude depends on the quotient of observer speed (T) and point distance (Z). For example, in an airplane flying high above the ground optic flow speed is very low even for very high forward speed of the plane. Thus, distance can only be calculated when the observer speed is known, which is usually not the case.

►*Time-to-Contact*. Information in the optic flow allows to estimate the time-to-contact or the time-to-passage with an obstacle during forward motion. By itself, the speed of an optic flow vector of a particular object is insufficient for the estimation of distance to the object (because it depends on T/Z) but a combination of speed with object size or of speed with the object's visual angle allows a direct calculation of time-to-contact. This information may be used to control braking or catching and to control running speed and direction for the intersection with a target object (for instance in ball sports). An overview can be found in [6].

►*Path Integration*. By integrating the speed of the optic flow over time an estimate of the travel distance or path length of an extended movement can be obtained. This estimate is subject to a scale factor since the speed of the flow depends on both the speed of the self-movement and the distance to the objects in the environment, but in many natural circumstances the height of the observer above the ground can provide the required scale. The estimation of travel distance from optic flow is based on an the integration of an estimate of observer velocity that is derived from the optic flow [7].

Heading. Heading refers to the direction of the movement of the observer. Gibson's original proposal for the use of optic flow was the identification of the heading (for example when landing an aircraft) by locating the focus of expansion in the flow field. Most optic flow research since then has centered on heading perception (overviews in [8] and [9]). Indeed, human observers are quite accurate in finding the focus of expansion in an expanding flow field. However, the situation is much more complicated because in most natural situations the optic flow on the retina is influenced by rotations and the flow field does not contain a focus of expansion (cf. Fig. 1). Yet, geometric calculations prove that the optic flow in these cases also contains sufficient information to separate the translational and rotational contributions if several flow vectors are available [1]. Many computational algorithms have been developed for this task, among them a few that are formulated as biologically plausible neurocomputational models (overview in [2]). Human observers can indeed estimate heading from flow fields of translation and rotation with reasonable accuracy (a few degrees of visual angle). An important finding was that heading estimation can be performed solely from the information in the flow field, i.e., from the direction and speed of the flow vectors, without any other sensory signals necessary. However, in natural situations eye movements that influence the structure of the retinal flow are accompanied by extra-retinal eye movement signals such as the ►efference copy signal or eye muscle ►proprioception. These signals are also used in optic flow analysis and increase the accuracy of the heading estimate. Rotational contributions to the retinal flow may also arise from movements on a curved path, in addition to, or instead of eye movements. Therefore, a separation of translational and rotational contributions may only provide the momentary or instantaneous heading but not the full information about the future path of the observer, since the rotational contributions are ambiguous. Estimations of path curvature, which are required for steering for instance, can be derived from successive independent heading estimates or from a combination of optic flow and extraretinal eye movement signals. Alternatively, specialized behavioral strategies, such as fixating a specific point in the flow field, may allow the estimation of steering-relevant information directly from the retinal velocities.

Although the above descriptions refer to human observers, optic flow is used for such behavioral tasks throughout the animal kingdom (see [2] for several examples). The use of optic flow for the control of speed, distance, time-to-contact, and course control has been shown in insects, birds, and mammals, exemplifying the ecological importance of optic flow. Moreover, the above descriptions show that optic flow is often part of multi-modal mechanisms for behavioral control, interacting with ►proprioceptive, vestibular, and internal feedback signals. Exposure to optic flow is also known to induce ►vection, the subjective feeling of self-movement in a physically static observer.

Neurophysiological Processing

In the visual system of primates visual motion information is routed via V1 and V2 to the ►middle temporal (MT) and subsequently to the ►medial superior temporal area (area MST) and other visual areas in the parietal lobe. Most clearly related to optic flow is area MST (detailed reviews in [2]). Many neurons in area MST respond selectively to entire optic flow patterns and not just to an individual motion vector in a particular flow field. A neuron might respond selectively to a particular flow pattern, such as an expansion as in Fig. 1c, but when tested with small stimuli the selectivities in subfields of the ►receptive field do not match one-to-one the pattern of the preferred large flow field. Thus, MST neurons are genuinely selective for optic flow. Their selectivity arises from complex interactions between selectivities in local subfields. Functional ►brain imaging in humans has confirmed an area selective for optic flow which is part of the human ►MT± complex.

When tested with multiple different flow patterns such as visual expansions, rotations and translations, MST reveals a continuum of response selectivities. Some neurons respond to several different patterns or to flow fields that combine translational and rotational contributions. Instead of classifying the selectivity of MST neurons by the preferred pattern of flow it is also possible to describe their selectivity in terms of heading. Indeed, it is possible to calculate heading from the firing rates of the neuronal population in MST. Next to visual motion signals, area MST also receives extra-retinal eye movement information. This information is used to counteract the effects of eye movements on the retinal flow and maintain selectivity for heading in the presence of eye movements. There are also interactions with vestibular signals during self-motion.

Other areas of the parietal lobe, the ►ventral intraparietal area (VIP) and area 7A, as well as the ►fundus of the superior temporal sulcus (FST) also respond to optic flow. Neurons in area MT, the major input to area MST, respond to optic flow but their responses can be explained by their selectivity to local image motion within their receptive field. However, some global properties of the visual field map in MT seem related to optic flow analysis. Preferred speeds increase with eccentricity similar to the increase of speed with eccentricity in typical flow fields. The distribution of preferred directions for neurons with peripheral receptive fields is biased towards centrifugal motion similar to the radial motion directions in a typical optic flow. The increase of the receptive field sizes with eccentricity is well adapted to the size of image patches over which neighboring flow signals are uniform. These patches are small in the center of the visual field, where optic flow vectors point in different directions, and large in the peripheral visual field where neighboring flow vectors are usually very similar. Computational modeling shows that this adaptation of receptive field sizes leads to significant noise reduction in the optic flow representation in area MT.

As mentioned above, optic flow is used by many animals. A brief description of the neuronal pathways of optic flow analysis in birds can be found in the essay on *visual-vestibular interactions*. In flies, optic flow is analyzed by a small number of neurons of the horizontal (HS) and the vertical (VS) system in the lobula plate (Krapp in [2]). Unlike neurons of primate MST, which show no simple correlation between local motion selectivities and flow patterns selectivity, the flow selectivity of these neurons in the fly is matched by the sensitivity to local motion in subfields of their very large receptive fields. These neurons seem to form matched filters for particular flow patterns. Like in primate MST, information about the translation and rotation of the animal can be decoded from the population activity.

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Optic Flow Dependent OFR

Definition

►Ocular Following Responses (OFR).

►Oculomotor Control
►Optic Flow

Optic Nerve

Definition

The optic nerve is the portion of the visual pathway between the retina and lateral geniculate nucleus of the thalamus that lays rostral to the optic chiasm. The continuation of the path caudally is the optic tract. The cell body of origin for this pathway is the ganglion cell in the retina.

Optic Neuritis

Definition

Sudden inflammation of the ►optic nerve occurring most often between 20 and 40 years of age, and may be a ►demyelinating disease of unknown origin or a co-manifestation of ►multiple sclerosis. The inflammation may occasionally be the result of a viral infection.

►Multiple Sclerosis