This encyclopedia entry appears as:

Scholl, B. J., & Flombaum, J. I. (2010). Object persistence. In B. Goldstein (Ed.), *Encyclopedia of Perception*, Volume 2 (pp. 653 - 657). Thousand Oaks, CA: Sage Publications.

Object Persistence

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Suppose that while playing tennis, an unfortunate swing propels your tennis ball out of the court and into some bushes. When you go to retrieve it, you find two tennis balls there. Which is yours? This is a type of *correspondence problem*: you must determine which of the two tennis balls corresponds to the one that you just hit out of the court. Though we are seldom explicitly aware of it, the visual system faces this type of problem thousands of times per day, whenever we encounter an object. On every such encounter, the visual system must determine whether a current bit of visual stimulation reflects a new object in the field of view, or an object that was already encountered a moment ago. This is the challenge of *object persistence*: the perception of the world not only in terms of discrete objects, but in terms of objects that retain their identities as the same individuals over time and motion. This entry notes how the problem of object persistence features in several aspects of perception, and it describes some of the ways that persistence is determined in visual processing.

The computation of object persistence in perception seems to happen instantly and effortlessly, but like many aspects of perception (from perceiving depth to perceiving faces), a great deal of processing must occur to arrive at the 'effortless' percept of persisting objects. If the visual system did not solve this type of problem so frequently and so efficiently, though, visual experience would be incoherent: we would be able to perceive objects, but it would be as if the world was created from scratch at every instant. On a street corner, for example, you might see a car *there*, then a car *there*, then a car *there* — with no recognition that you are seeing the *same* car at different times and places, as it moves down the street. Complicating things further, an object might only be re-encountered after a brief pause, due to a blink or to a period of visual occlusion, and when the object reappears it might be in a different location, or have changed some of its visual features.

Three Examples

Object persistence plays a role in many types of visual processing. Three examples are described here.

Apparent Motion

Object persistence is a crucial feature of even one of the simplest possible visual stimuli: two flashes of light, seen at different times and different places. If the flashes are far enough apart in time or space, they will be seen as two independent visual events. If they appear nearby and in quick succession, though, then the visual system interprets the flashes as a single event, and we see a single object that seems to move quickly from one location to the other. This phenomenon of *apparent motion*, in essence, reflects perception making an 'unconscious inference' about persistence (in an automatic and hardwired way): the visual system decides under such circumstances that the second flash was the *same object* as the first flash, and so constructs a percept of motion to link them.

The Tunnel Effect

A similar situation arises in more natural events, as when a moving object disappears behind an occluder, and then an object emerges from the other side. In this situation, is the second object the *same individual* as the first object? In fact, if the movements are smooth and natural enough, we will see the event in terms of the uninterrupted and uniform motion of a single object behind the occluder. This is not a decision that is made consciously, but it is rather a type of automatic inference that is made in visual processing. Indeed, in this type of *tunnel effect*, we sometimes irresistibly see a single moving object even when we *know* for certain that the display contained two separate objects. In fact, the tunnel effect is equally compelling even when the two objects have entirely different surface features (e.g. colors and shapes): in this case, we see a single object that changes its features while occluded, rather than two separate objects, one of which must have been initially 'hiding' behind the occluder.

Multiple Object Tracking

When trying to cross a street, you may have to attend carefully in order to keep track of how and where several cars are moving. When playing basketball, you may have to keep track of how and where several teammates and opponents are moving. These situations have been studied in attention research in the *multiple object tracking* (MOT) task, created by Zenon Pylyshyn. Observers initially see a number of identical looking objects. A subset of these are then flashed to indicate their status as targets, after which all of the (again identical) objects begin moving independently and unpredictably about the display. When they stop moving, observers must indicate which of the objects are the original targets. Observers are able to succeed at MOT when tracking up to 3 or 4 objects, but tracking more is nearly impossible for most people. This ability reveals how sustained object-based attention may give rise to a type of object persistence, and the constraints on MOT reveal that we are only able to perceive a small number of persisting objects at a time.

Object Files

Object persistence is thought to be determined in on-line perception at the stage that is often called "mid-level vision". At this level, objects may be represented as the same individuals over time despite changes to both their lower-level visual features (e.g. red, round) and their higher-level category descriptions (e.g. "apple"). The challenge of object persistence can be considered in terms of these kinds of mental representations: the visual system must decide whether each bit of stimulation reflects an object that was already encountered (which might occasion the *updating* of an existing object representation), or a new one (which might occasion the *creation* of a new object representation).

The most influential theory of such representations is the *object file* framework put forth by Anne Treisman and Daniel Kahneman. An object file is a visual representation which 'sticks' to a moving object over time on the basis of how and where that object moves, and stores (and updates) information about what that object looks like. In this way, object files help to construct our conscious perception of objects, telling us 'which went where', and underlying the perception of object persistence despite changes in either what an object looks like or momentary periods of occlusion. This framework can be used to interpret the examples noted earlier in terms of underlying representations. We see apparent motion because the two flashes are represented by the same object file over time, rather than by two separate object files. Similarly, we see the tunnel effect because the two objects are represented by the same object file. And we are able to track multiple objects in the MOT task because we are able to keep the same object files assigned to the target objects as they move.

Beyond these types of perceptual phenomena, the operation of object files can also be measured in terms of an object-specific priming effect. Suppose that two objects are initially presented in a display, and distinct symbols (perhaps letters) appear briefly on each of them. The objects then move about the display for a brief period, after which a single 'probe' symbol appears on just one of the objects. A subject's task, in one variant of this type of experiment, is to press a key to indicate whether the final probe symbol was the same as *any* of the initially presented symbols. Subjects will be faster to indicate 'yes' than to indicate 'no' due to a type of display-wide priming. But their 'yes' responses will be even faster when the probe is the same symbol that initially appeared on *that same object*, compared to when it was the symbol that had initially appeared on the other object. This difference in response time is termed an *object-specific preview benefit* (OSPB). This effect can thus be used as an index of object persistence: manipulations which degrade object files will result in attenuated OSPBs.

Principles of Persistence

Researchers have made great strides in identifying some of the principles used by the visual system in order to perceive persisting objects. Three of the most salient principles are described here.

Continuity

A basic fact about the world is that objects cannot simply go in and out of existence over time. For two objects encountered at different locations to be subsequent stages of the same individual, there must be a spatiotemporally continuous path between them. If an object disappears at one location, and an object immediately appears at a different (spatially separated) location, then those two instances cannot be the same object. This constraint of continuity is used in visual processing (taking occlusion into account) to constrain whether two bits of stimulation are seen as the same object over time, and its role can be seen in each of the examples noted above. We only see apparent motion, for example, when the two flashes occur close enough in space and time (in which case the spatiotemporal proximity is judged to reflect a single swiftly moving object, instead of a coincidence). Similarly, we only see the tunnel effect when the two objects are linked by a smooth spatiotemporal trajectory; and we are only able to track multiple objects that move along what appear to be spatiotemporally continuous trajectories. The use of continuity to perceive persisting objects also comes online at an early age: even young infants appear to appreciate that objects must trace continuous paths (as evidenced in experiments that measure their looking times), and continuity is considered by some developmental researchers to be one of the principles of 'core knowledge' that help drive further learning about the visual world.

Cohesion

Another principle that determines object persistence is that of *cohesion*: an object must maintain a single bounded contour in order to be represented as persisting over time. This is also an intuitive defining characteristic of what it means to be an object in the first place: if you attempt to grab an object and only part of it comes away in your hand, then it must not have been a single object. The operation of cohesion as a constraint on object persistence can be seen in several ways. For example, multiple object tracking becomes very difficult if the objects fail to maintain unitary boundaries over time, and violations of cohesion such as an object splitting into two greatly attenuate the resulting OSPBs that are observed in object-specific priming studies. Cohesion is also thought by some to be a principle of 'core knowledge', and developmental researchers have shown that cohesion violations also cause young infants to lose track of objects.

Spatiotemporal Priority

In everyday life, we identify some objects as the same individuals over time not because of how they move, but because of what they look like: when you next see your best friend, for example, you will likely identify them not because you watched them trace a continuous path since your last encounter, but because they *look like* your best friend. This way of assessing persistence breaks down, though, when an object (such as your missing tennis ball) might look identical to other objects. Moreover, these two sorts of principles may come into conflict: suppose, for example, that an object traces a continuous trajectory but suddenly changes what it looks like. On such occasions, visual processing seems to apply a principle of *spatiotemporal priority*: when deciding whether an object is the same persisting individual from some earlier time, factors relating to how and where that object has moved will almost always trump factors relating to what the object looks like. For example, we may automatically see apparent motion between two flashes even if those flashes are very different colors and shapes, so long as they occur near enough in space and time. In such cases, we may thus see a red circle transform into a green square during its movement, rather than seeing two separate objects. Similarly, if the spatiotemporal trajectory linking two objects in the tunnel effect is fast and smooth enough, we may irresistibly see a single object (which changed its features while occluded) rather than seeing two separate objects (one pre-occlusion, one post-occlusion) with different properties. And, multiple object tracking is largely unaffected by changing surface features, so long as the objects move continuously. This spatiotemporal priority also appears to be a primitive principle of object persistence, since even non-human primates experience the tunnel effect in such situations. And spatiotemporal priority may be explained in terms of object files. Spatiotemporal factors are thought to control the construction and maintenance of such representations, but surface features are just along for the ride: when they change, the only result may be that the *contents* of the object file are modified.

The Importance of Persistence of Other Aspects of Perception

The importance of object persistence for perception can be appreciated not only by considering how we perceive the world, but also in how such computations influence other aspects of visual processing. Some of these connections must exist almost by definition. For example, the perception of *number* requires object persistence, since you cannot perceive multiple *distinct* objects without being able to recognize whether two objects are the same or different individuals. Object persistence also influences less obvious aspects of perception such as visual memory: changes are more easily detected between two stimuli that are encoded as the same persisting object. And neuroscientific studies show that principles such as spatiotemporal continuity influence neural representations of objects as the same over time — even in regions such as ventral cortex that are usually associated with the processing of what objects look like. Ultimately, the 'currency' of many perceptual processes may be *persisting* visual object representations.

See also:

Attention: Object-Based, Binding Problem, Event Perception, Motion Perception, Perceptual Development: Object Perception, Visual Memory

Suggested Further Readings

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