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Dispatches

# Object Perception: Where Do We See the Weight?

**A new study of the response of the human brain as subjects view objects of different weights they are about to lift shows that the weight of objects, which influences the way we act upon them, is represented in the ventral stream of the visual cortex.**

**Robert W. Kentridge**

Milner and Goodale's [1] hypothesis that the processing of visual information in the cerebral cortex can be both anatomically and functionally divided into two components has proved both influential and controversial. They suggested that information leaving primary visual cortex along projections travelling to the parietal lobe, the dorsal stream, is used for the visual control of action towards objects, whereas information passing from striate cortex through the temporal lobe, the ventral stream, is used in identifying objects. A study reported in this issue of *Current Biology* [2] reports important findings suggesting that properties of objects that influence the manner in which actions operate upon them can be represented in areas of the ventral stream. Specifically, the study shows that areas within the ventral stream respond selectively to objects with different weights independently of their responses to the visual properties of those objects. Crucially, visual information influences the force applied to objects before lifting action itself starts, and so this component of action must be determined by the visual properties of the object rather than simply being a response to kinaesthetic feedback. Of course, the weight of an object cannot be inferred directly from visual properties of objects, but we easily learn to associate visual properties with weight — after a little experience, we know by looking that a Styrofoam cup is lighter than a China one. By using objects that look identical but which subjects learn have different weights in one experiment, and objects that look as if they should be heavy, but which subjects learn are light (and vice versa) in a second experiment, Gallivan *et al.* [2] show that weight and the visual properties that are cues to weight, such as texture, are represented independently within areas in the ventral stream.

Gallivan *et al.* [2] used multivoxel pattern analysis of fMRI signals [3] in order to determine the areas of cortex in which expectations about the weight of objects were represented. Unsurprisingly, weight influences the pattern of activity in primary motor cortex as the object is lifted. The critical findings are that expectations of weight, either derived from repeated experience of lifting a specific object or from associations between the surface properties (colour and texture) of an object and its weight, could influence the pattern of response in ventral stream visual areas typically associated with perception of shape (lateral occipital cortex) and surface properties such as texture (posterior fusiform areas near the anterior portion of the colateral sulcus). The second experiment shows that weight-specific patterns of activity and patterns specific to the visual properties of stimuli can occur independently in the same area of cortex. These weight-specific patterns of activity were not found in early visual areas V1 and V2.

At first glance this new finding appears to challenge the two visual systems hypothesis, because it demonstrates that information about the weight of objects that influences action (specifically the force applied to lift the object) is represented in the ventral stream — the purported seat of object identification. However, this finding is not at odds with a more nuanced reading of Milner and Goodale's hypothesis. In contrast to the shape of an object and its position and orientation relative to our bodies, properties such as weight are not directly specified in the visual information available as we look at an object, but they are part of the object's identity. What does it mean to identify an object? Object identification is not simply object naming, it is recall of the constellation of properties and associations that distinguish *this* object from others. It is the process in which perception and memory become intertwined [4]. We might therefore view weight as being part of the identity of an object ('the heavy cylinder') rather than the directly specified spatial properties that determine, in a Gibsonian sense, how we may act upon it. Both types of information influence our actions [5]. Knowledge of the properties of objects beyond their geometry typically constrains the range of actions we apply to objects. We could grasp a mug so that its open end remains upwards or tilts sideways, but knowledge of the consequences if the mug is full affects the type of grasp we make.

Within the ventral stream there are distinct areas that respond to different properties of objects. Some of these areas seem to be specific to particular visual properties such as texture, colour or glossiness [6–9], while others respond to multiple surface properties [10,11]. One interpretation of these multiple representations is that areas responsive to combinations of surface properties are encoding more conceptual, as opposed to visual, properties of objects. In monkeys, the more conceptual encoding occurs in more anterior areas [12], whereas more posterior areas respond to specific visual properties. Consistent with this, the area in the current study that responded both to visual properties and to expectations of weight coincides approximately with the areas of anterior collateral sulcus described by Cant, Goodale and their colleagues [10,11] as opposed to the more posterior area identified by Cavina-Pratesi *et al.* [6,7].

We should not be surprised that information in the ventral stream can influence action. There are many ways in which the dorsal and ventral streams can interact [13]. The dorsal and ventral streams project to a number of common areas (for example, TEO in the temporal lobe, prefrontal cortex). There are extensive cross-connections between dorsal and ventral streams. Feedback connections from either stream reach early visual areas that project to both streams. Independence between dorsal and ventral streams will generally only become apparent in normal observers (with intact brains) when responses are so speeded that there is not time for interaction through these pathways to occur. Neither the presence of these connections nor evidence such as that found by Gallivan and his colleagues invalidates Milner and Goodale's two visual systems hypothesis. Gallivan's findings, do, however, highlight the need to avoid overly simplistic interpretations of it.

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# Golgi Apparatus: Finally Mechanics Comes to Play in the Secretory Pathway

**New findings report a mechanical role for actin in Golgi organization and vesicular trafficking. An elegant study uses optical tweezers and live-cell imaging to demonstrate the effects of a mechanical constraint on the dynamics of secretory membrane trafficking, combining physical experimental approaches with *in cellulo* studies of endomembranes.**

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In the last 30 years, a huge amount of progress has been made in the identification and mechanistic understanding of molecular components that participate in the trafficking of lipids and proteins along the secretory pathway. The importance of membrane trafficking in health and disease was recognized last year with the Nobel Prize in Medicine and Physiology to well-known and recognized pioneers of the field (Randy Scheckman, James Rothman and Thomas Südhof). One might therefore be tempted to think that the field of membrane trafficking no longer holds any great new 'surprises' or insights and might even fall into a state of lethargy (if not of decadence). But what an incorrect assumption! There is at least one aspect that still remains largely elusive in membrane trafficking: the contribution and functional relevance of physical forces on the shape, organization, and function of endomembranes. Published studies [1–3] have undoubtedly provided (and continue to provide) great progress in addressing the contribution of membrane tension and curvature to coat-induced budding and molecular sorting and to membrane fission of transport carriers ([4] and references therein). In a recent issue of *Current Biology*, an elegant study by Guet *et al.* [5] combining physical approaches with confocal microscopy in living cells reveals that Golgi membranes are flexible and mechanically coupled, that actin confers rigidity to the Golgi apparatus, and that a mechanical constraint produces a switch from vesicular to tubular trafficking, linking forces with membrane fission.

On one hand, when we think of 'forces' in the cell, the main subcellular contributor is the cytoskeleton, composed largely of two highly dynamic (and regulated) polymers —microtubules and actin filaments. On the other hand, when we think of membrane trafficking in the secretory pathway, the Golgi apparatus immediately comes to our mind. In most organisms, the Golgi is composed of one or more stacks of closely apposed flattened membranes called cisternae. In animal cells, these stacks are arranged end to end to form the 'Golgi ribbon'. It is well known that the cytoskeleton has a significant role in structuring the Golgi apparatus: microtubules participate in the lateral connection of the Golgi ribbon and in its polarity, and actin filaments are involved in the maintenance of the flattened shape of cisternae [6,7]. Accompanying both cytoskeletal elements is the Golgi matrix, the structural scaffold that provides proteinaceous cross-bridges linking adjacent Golgi cisternae. Members of the Golgi reassembly and stacking protein (GRASP) and golgin families of proteins are components of the matrix [8]. These peripheral membrane proteins, together with microtubules and actin filaments (and their respective motors), stack the Golgi cisternae together.

Gaining insight into cellular membranes and their organization requires a combination of physical and cell biological approaches. Optical tweezers [9] allow for tight